# Appendix D
# Static GPS Survey Examples

*Section I*
*Survey No. 1: HORIZONTAL CONTROL GPS SURVEY (Ukiah Airport, California)*

## D-1. Planning Phase

The GPS survey was planned for 25 April 1989 in the vicinity of Ukiah Airport, Ukiah, California.

*a.* A diagram of the project area is shown in Figure D-1.

*b.* Four SPS (C/A-code) GPS carrier phase tracking receivers were used for the survey, one person per receiver. In actuality, because the personnel were inexperienced in conducting a GPS survey, a fifth person was also used. The fifth person was used as a "runner" who can be called upon during the survey to aid in smoothing out any complications ( e.g., aiding in overall communication and coordination, parts retrieval in case of breakdown, bad power source, blown fuse, misplaced equipment, forgotten measurement device or power cord, as well as any other possible complication). Communication between personnel was by two-way radio. Care was taken in choosing and operating the two-way radio near the GPS survey so that the radio transmitter and receiver chosen, when in operation, would not interfere with the GPS receiver.

*c.* Prior to data collection, the stations were inspected and found to be acceptable (easy accessibility, no obstruction or possible multipath sources, and at least 20° satellite visibility above the horizon).

*d.* The date 25 April 1989 corresponds to Julian calendar day 115. Calpella, Perry, and Ukiah Airport were stations with established horizontal control. Pier 1 and Pier 2 were stations requiring horizontal coordinates accurate to 1:10,000 (refer to Figure D-2). Therefore, the following station conventions for Session 1 of the survey were:

Pier 1 - Station 20011151
Pier 2 - Station 20021151
Calpella - Station 20131151
Ukiah Airport - Station 20141151

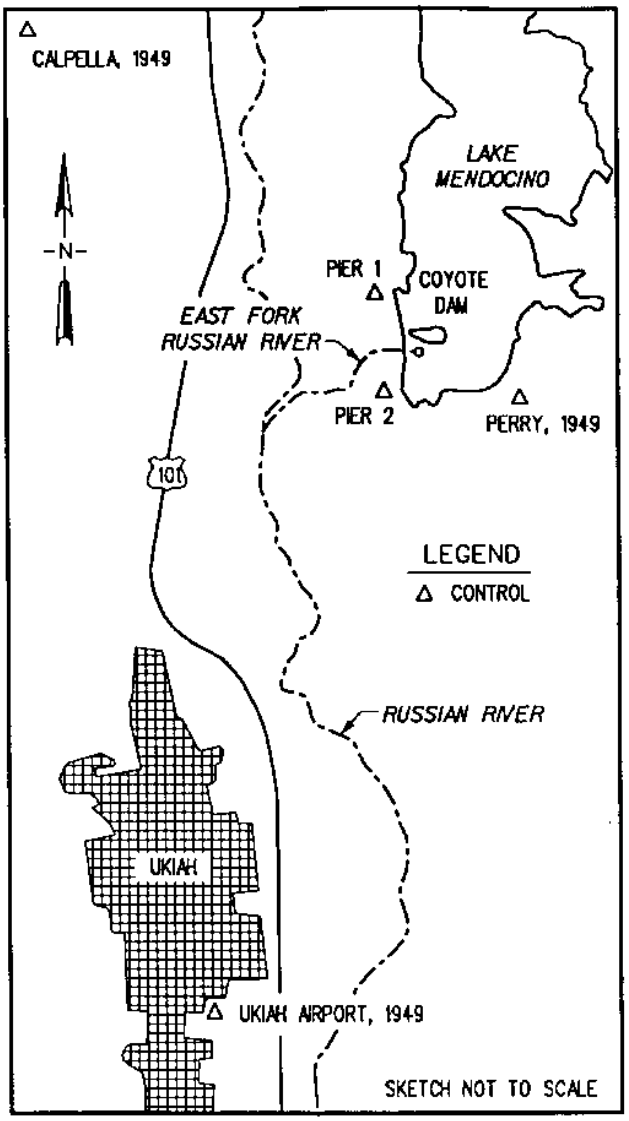



**Figure D-1. Ukiah project area**

It is important to note that this station convention was used for this survey because the receiver used only allowed numeric input of station names. Most newer receivers allow alphanumeric inputs for station names which provides more flexibility in station naming. (Consult the GPS manufacturer literature for further explanation and guidance on the receiver's station naming convention.)

*e.* A satellite visibility plan (a software package that produces a hard copy listing of satellite constellations and

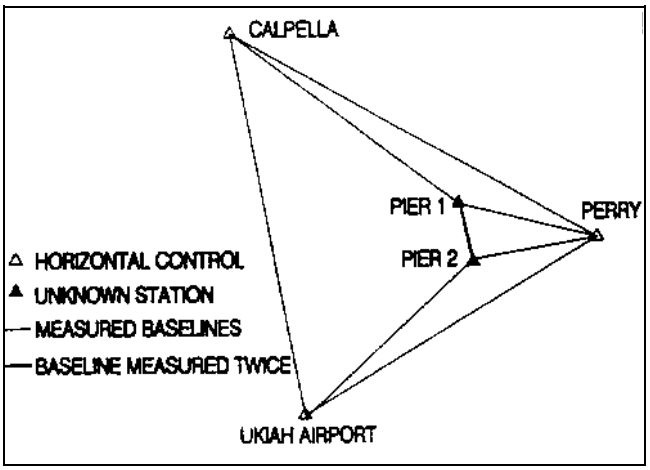



**Figure D-2. GPS project diagram (Ukiah)**

time availability based on ephemerides) was run for the project location. The satellite visibility was run with the most up-to-date ephemeris for the period of observation, using four-satellite visibility, and with a cutoff elevation angle of 20°. An up-to-date ephemeris was used to ensure the satellite visibility formulated was the most accurate. Four-satellite visibility was run in order to formulate accurate 3D solutions. A cutoff elevation of 20° was chosen in order to minimize any diffusion or dispersion of the signal by the atmosphere which in turn may cause errors in the solution as the satellites pass near the horizon. The satellite visibility plan produced for the Ukiah project is shown below.

All-In-View PDOP for Ukiah

Date: 25 Feb 1990 Latitude: 39° 12' 30" N
Time: 4:00 -> 4:00 Longitude: 123° 10' 30" W
Cutoff Elevation: 20 Zone: - 7:00

| Satellite Constellation | Time Rise | Time Set | dT | PDOP Rise | PDOP Set |
|---|---|---|---|---|---|
| 6 9 11 13 | 21:55 | 22:03 | 0:08 | 4.9 | 5.0 |
| 6 9 11 12 13 | 22:02 | 22:33 | 0:30 | 3.8 | 3.6 |
| 6 9 11 12 13 19 | 22:32 | 23:18 | 0:45 | 3.2 | 3.3 |
| 3 6 9 11 12 13 19 | 23:17 | 23:48 | 0:30 | 2.9 | 3.0 |
| 3 9 11 12 13 19 | 23:47 | 1:08 | 1:20 | 4.2 | 4.2 |
| 3 11 12 13 19 | 1:07 | 1:22 | 0:15 | 4.9 | 5.0 |
| 3 12 13 19 | 1:22 | 2:20 | 0:58 | 22.7 | 31.6 |

The portion of the satellite visibility where the PDOP is near 5.0 m/m or below are times when the satellite geometry is conducive for conduct of a survey. A PDOP near or below 5.0 m/m does not guarantee a successful survey but it does indicate good satellite geometry during that moment of the survey (see Chapter 5 for further information on PDOP).

*f.* From the satellite visibility plan, it was decided to conduct three sessions during the survey. Travel between survey sites, time to set up and take down the equipment before and after the survey, receiver warm-up time, time of survey (at least an hour allotment for survey data collection, but more than an hour if at all possible), and possible time loss due to unforeseeable problems or complications were taken into account before deciding on a specific session schedule. The final survey session schedule is shown in Table D-2.

**Table D-2**
**Final Survey Session Schedule**

| Session | Start Time | Stop Time |
|---|---|---|
| 1 | 21:55 | 22:55 |
| 2 | 23:38 | 00:38 |
| 3 | 01:23 | 02:20 |

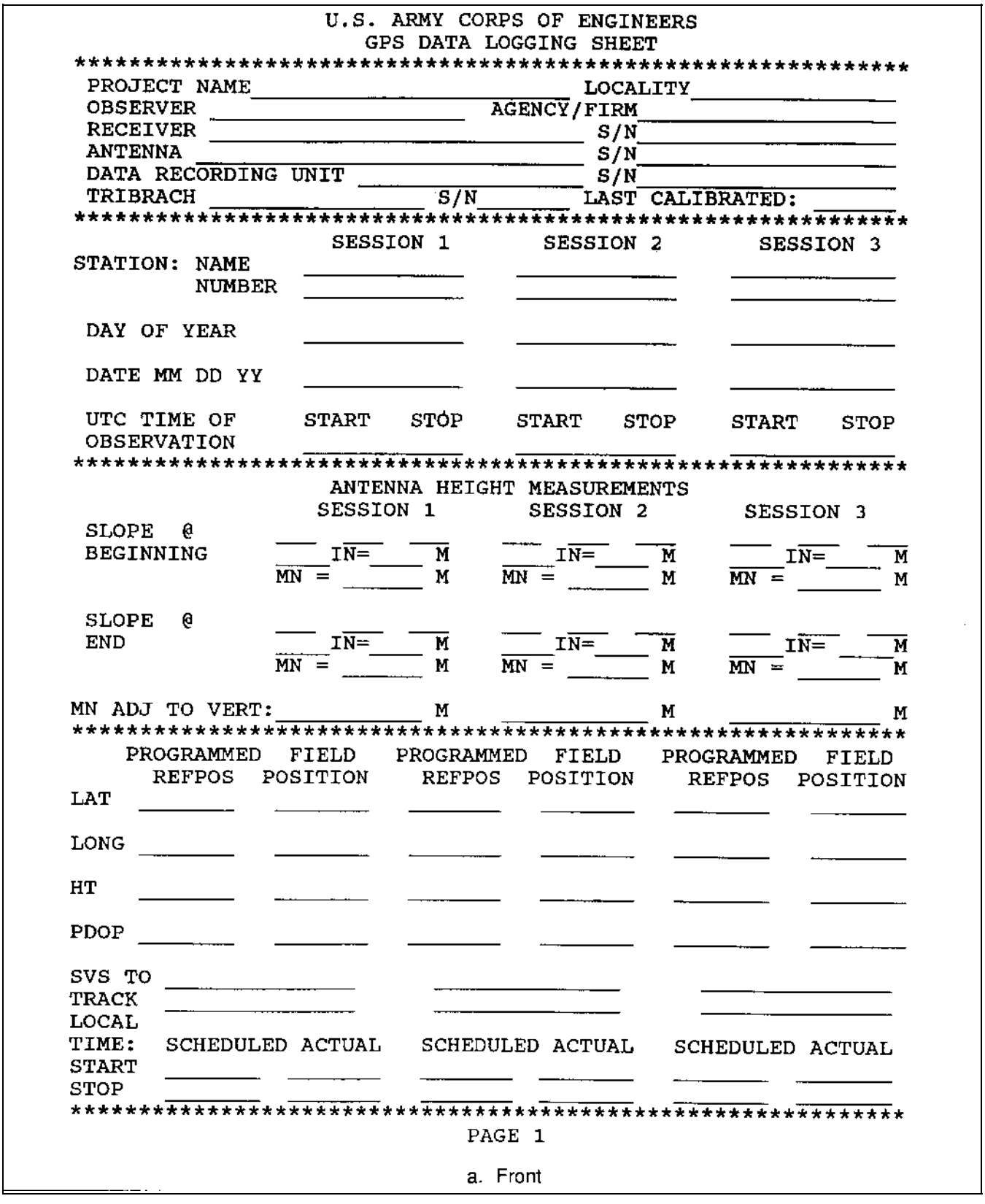
It was further decided which stations would be occupied during each session. Station occupation was designed to minimize travel time and to add to the overall efficiency of the survey. The station occupation schedule was planned as shown in Table D-3.

**Table D-3**
**Station Occupation Schedule**

| Session | Station | Station | Station | Station |
|---|---|---|---|---|
| 1 | Calpella | Ukiah Airport | Pier 1 | Pier 2 |
| 2 | Calpella | Perry | Pier 1 | Pier 2 |
| 3 | Ukiah Airport | Perry | Pier 1 | Pier 2 |

*g.* A GPS station observation log is generally filled out prior to conduct of the survey. An example of a GPS log is shown in Figure D-3. The log must be filled out for each of the stations occupied in order to have a written record of the actual survey and as an aid for the personnel occupying each of the stations.

*h.* Portions of the GPS station observation log were filled out prior to data collection. These portions included the station name, start date, GPS 8-character ID for each session, project name, project location, observer name, approximate receiver position (latitude, longitude, and elevation), session scheduled start and stop times, and requisite tracking equipment information. In this case, six GPS station observation logs were filled out, one each



U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

PROJECT NAME _____ LOCALITY _____
OBSERVER _____ AGENCY/FIRM _____
RECEIVER _____ S/N _____
ANTENNA _____ S/N _____
DATA RECORDING UNIT _____ S/N _____
TRIBRACH _____ S/N _____ LAST CALIBRATED: _____

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| STATION: NAME | | | |
| NUMBER | | | |
| DAY OF YEAR | | | |
| DATE MM DD YY | | | |
| UTC TIME OF OBSERVATION | START STOP | START STOP | START STOP |

ANTENNA HEIGHT MEASUREMENTS

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| SLOPE @ BEGINNING | ___ ___ ___ IN=___ M MN = ___ M | ___ ___ ___ IN=___ M MN = ___ M | ___ ___ ___ IN=___ M MN = ___ M |
| SLOPE @ END | ___ ___ ___ IN=___ M MN = ___ M | ___ ___ ___ IN=___ M MN = ___ M | ___ ___ ___ IN=___ M MN = ___ M |
| MN ADJ TO VERT: | ___ M | ___ M | ___ M |

| | PROGRAMMED REFPOS | FIELD POSITION | PROGRAMMED REFPOS | FIELD POSITION | PROGRAMMED REFPOS | FIELD POSITION |
|---|---|---|---|---|---|---|
| LAT | | | | | | |
| LONG | | | | | | |
| HT | | | | | | |
| PDOP | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| SVS TO TRACK LOCAL TIME: | SCHEDULED | ACTUAL | SCHEDULED | ACTUAL | SCHEDULED | ACTUAL |
| START | | | | | | |
| STOP | | | | | | |

PAGE 1

a. Front

**Figure D-3. Example GPS station observation log (front and back) (Continued)**

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| ANT CABLE LENGTH | | | |
| POWER SUPPLY | | | |
| WEATHER CONDITIONS | | | |
| MONUMENT TYPE | | | |
| EXACT STAMPING | | | |
| AGENCY CAST IN DISK | | | |

SKETCH OF SITE

| SESSION 1 | SESSSION 2 | SESSION 3 |
|---|---|---|
| | | |

Describe any abnormalities and/or problems encountered during the survey, include session number, time of occurence and duration.

PAGE 2

b. Back

Figure D-3. (Concluded)

for: Calpella (Sessions 1 and 2), Ukiah Airport (Session 3), Ukiah Airport (Session 1), Perry (Sessions 1 and 2), Pier 1 (Sessions 1, 2, and 3), and Pier 2 (Sessions 1, 2, and 3). An example of a GPS station observation log for Pier 2 is shown in Figure D-4.

## D-2. Actual Survey Operation

These portions of the GPS station observation log which were not filled out during the planning phase of the survey were filled out during data collection. An example of the GPS station observation log for Pier 2, filled out after data collection, is shown in Figure D-5.

*a.* The key to proper data collection is the correct setup of the equipment (tripod, receiver, and power source) and correct antenna height measurements (height of the antenna above the mark).

*b.* Figure D-6 shows personnel correctly taking an antenna height measurement over a temporary monument. Figure D-7 illustrates a typical antenna setup with the following equation detailing the antenna height correction.

$$v = \sqrt{(s)^2 - (r)^2} \qquad \text{(D-1)}$$

where

$v$ = corrected vertical height distance of the antenna center above the mark

$s$ = slope distance measurement derived from the average of several antenna height measurements made

$r$ = antenna radius

*c.* When measuring the antenna height during this survey, the procedure below was followed in order to ensure an accurate reading:

(1) The slope distance from the north point of the antenna to the center of the monument was measured to the nearest millimeter (0.001 m). Measurement was also done in non-SI units (inches) to the nearest 1/32 of an inch. This value then was compared to the metric value measured earlier in order to detect blunders.

(2) Similar measurements were also taken from the south point of the antenna to the center of the monument.

(3) The resultant north and south slope distances were averaged.

(4) *Example*: (Refer to Figure D-5.)

(a) Tripod set up flat on a dock.

(b) The north side measure up for session 1 = 0.120 m.

(c) The south side measure up for session 1 = 0.120 m.

(d) An extra “Check Measurement” was also taken for the measure up for Session 1 and was found to be 0.394 ft.

(e) As a check: (0.394 ft.) x (1 m/3.281 ft.) = 0.120 m.

(f) This value was recorded in the GPS station observation log.

*d.* Each GPS receiver was operated in direct accordance with the manufacturer’s instructions, procedures, and/or guidance.

*e.* No problems were encountered during the survey sessions.

## D-3. Post-Processing Observation Data

All observation data recorded were downloaded from the receivers to a 5.25-in. floppy disc. The downloading procedures detailed in the manufacturer’s operating manuals were strictly adhered to.

*a.* Once the observation data were downloaded, preprocessing of data was performed. Preprocessing of data included checking the station names, antenna heights, latitude, longitude, and elevation of the points, as well as applying any required corrections. In general, most GPS processing software requires the antenna slope height be corrected to vertical at some point in the survey, usually during the pre-processing phase. (Consult receiver/ software manufacturer guidelines for specifics.)

*b.* The data for the Ukiah project were post-processed using TRIMBLE software, but in general, all post-processing software produces similar results. The

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

PROJECT NAME COYOTE DAM LOCALITY UKIAH, CA
OBSERVER LARRY LAMB AGENCY/FIRM COE, SACRAMENTO DISTRICT
RECEIVER TRIMBLE 4000 SL S/N 2820A00223
ANTENNA TRIMBLE MICRO SL S/N 2816A00224
DATA RECORDING UNIT RECEIVER S/N 2820A00224
TRIBRACH WILD GDF 22 S/N N/A LAST CALIBRATED: 4/24/89

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| STATION: NAME | PIER 2 | PIER 2 | PIER 2 |
| NUMBER | 2002 | 2002 | 2002 |
| DAY OF YEAR | 115 | 115 | 115 |
| DATE MM DD YY | 4/25/89 | 4/25/89 | 4/25/89 |
| UTC TIME OF OBSERVATION | START 04:56 STOP 05:55 | START 06:10 STOP 07:38 | START 07:55 STOP 09:20 |

ANTENNA HEIGHT MEASUREMENTS

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| SLOPE @ BEGINNING | ___ ___ ___ IN= ___ M MN = ___ M | ___ ___ ___ IN= ___ M MN = ___ M | ___ ___ ___ IN= ___ M MN = ___ M |
| SLOPE @ END | ___ ___ ___ IN= ___ M MN = ___ M | ___ ___ ___ IN= ___ M MN = ___ M | ___ ___ ___ IN= ___ M MN = ___ M |
| MN ADJ TO VERT: | ___ M | ___ M | ___ M |

| | PROGRAMMED REFPOS | FIELD POSITION | PROGRAMMED REFPOS | FIELD POSITION | PROGRAMMED REFPOS | FIELD POSITION |
|---|---|---|---|---|---|---|
| LAT | 39-12-30 | | 39-12-30 | | 39-12-30 | |
| LONG | 123-10-30 | | 123-10-30 | | 123-10-30 | |
| HT | 244.0 | | 244.0 | | 244.0 | |
| PDOP | 3.6 | | 4.8 | | 4.0 | |
| SVS TO TRACK | 02,03,06,09 11,12,13,14 | | 02,03,06,09 11,12,13,14 | | 03,06,09,11 12,13,14,16 | |
| LOCAL TIME: | SCHEDULED | ACTUAL | SCHEDULED | ACTUAL | SCHEDULED | ACTUAL |
| START | 21:55 | | 23:38 | | 01:20 | |
| STOP | 22:55 | | 00:38 | | 02:20 | |

PAGE 1

a. Front

Figure D-4. GPS station observation log, presurvey (Continued)

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

| | SESSION 2 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| ANT CABLE LENGTH | 100 ft | 100 ft | 35 ft |
| POWER SUPPLY | 12v DC | 12v DC | 12v DC |
| WEATHER CONDITIONS | | | |
| MONUMENT TYPE | "C" (SET IN PIER) | ← SAME | ← SAME |
| EXACT STAMPING | PIER 2 1953 | ← " | ← " |
| AGENCY CAST IN DISK | COE | ← " | ← " |

SKETCH OF SITE

SESSION 1 | SESSION 2 | SESSION 3

Describe any abnormalities and/or problems encountered during the survey, include session number, time of occurence and duration.

PAGE 2

b. Back

**Figure D-4. (Concluded)**

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

PROJECT NAME COYOTE DAM LOCALITY UKIAH, CA
OBSERVER LARRY LAMB AGENCY/FIRM COE SACRAMENTO DISTRICT
RECEIVER TRIMBLE 4000SL S/N 2820A00223
ANTENNA TRIMBLE [illegible]0 SL S/N 2816A00224
DATA RECORDING UNIT RECEIVER S/N 2820A00224
TRIBRACH WILD GDF 22 S/N N/A LAST CALIBRATED: 4/24/89

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| STATION: NAME | PIER 2 | PIER 2 | PIER 2 |
| NUMBER | 2002 | 2002 | 2002 |
| DAY OF YEAR | 115 | 115 | 115 |
| DATE MM DD YY | 4/25/89 | 4/25/89 | 4/25/89 |
| UTC TIME OF OBSERVATION | START 04:56 STOP 05:55 | START 06:10 STOP 07:38 | START 07:55 STOP 09:20 |

ANTENNA HEIGHT MEASUREMENTS

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| SLOPE @ BEGINNING | 0.120 0.120 0.120<br>4 12/16 IN=0.121 M<br>MN = 0.120 M | 0.116 0.116 0.116<br>4 9/16 IN=0.116 M<br>MN = 0.116 M | 0.123 0.124 0.124<br>4 14/16 IN=0.124 M<br>MN = 0.1238 M |
| SLOPE @ END | 4 11/16 4 12/16 4 11/16<br>0.120 IN=4 13/16 M<br>MN = 0.120 M | 4 9/16 4 9/16 4 9/16<br>0.116 IN=4 9/16 M<br>MN = 0.116 M | 4 13/16 4 14/16 4 14/16<br>0.123 IN=4 13/16 M<br>MN = 0.1230 M |
| MN ADJ TO VERT: | 0.120 M | 0.116 M | 0.1234 M |

| | PROGRAMMED REFPOS | FIELD POSITION | PROGRAMMED REFPOS | FIELD POSITION | PROGRAMMED REFPOS | FIELD POSITION |
|---|---|---|---|---|---|---|
| LAT | 39-12-30 | 39-12-22.64 | 39-12-30 | 39-12-22.48 | 39-12-30 | 39-12-22.81 |
| LONG | 123-10-30 | 123-10-33.42 | 123-10-30 | 123-10-33.20 | 123-10-30 | 123-10-33.62 |
| HT | 244.0 | 210.6 | 244.0 | 199.8 | 244.0 | 222.8 |
| PDOP | 3.6 | — | 4.8 | — | 4.0 | — |
| SVS TO TRACK | 02,03,06,09<br>11,12,13,14 | | 02,03,06,09<br>11,12,13,14 | | 03,06,09,11<br>12,13,14,16 | |
| LOCAL TIME: | SCHEDULED | ACTUAL | SCHEDULED | ACTUAL | SCHEDULED | ACTUAL |
| START | 21:55 | 21:56 | 23:38 | 23:10 | 01:20 | 00:55 |
| STOP | 22:55 | 22:55 | 00:38 | 00:38 | 02:20 | 02:20 |

PAGE 1

a. Front

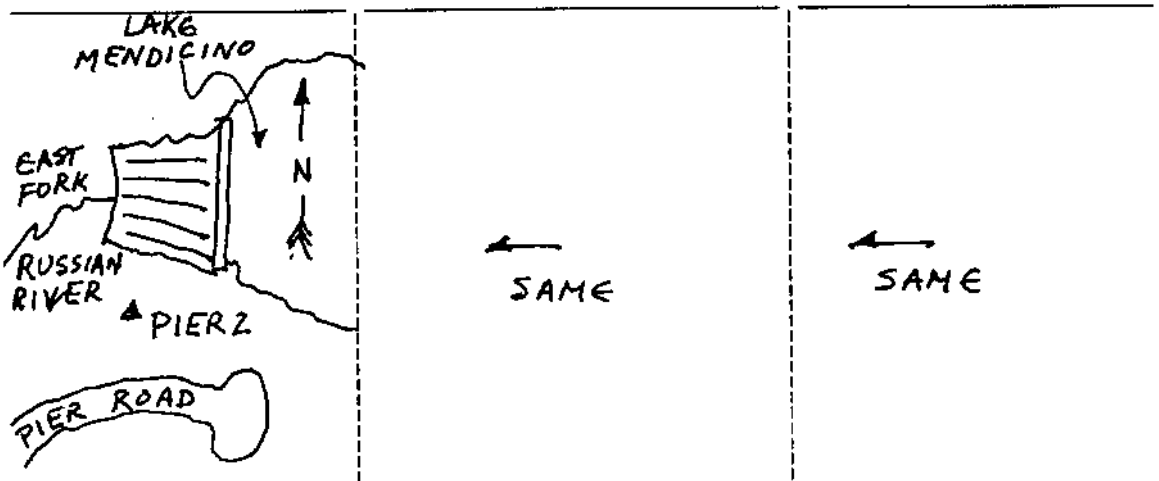
**Figure D-5. GPS station observation log, postsurvey (Continued)**

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

| | SESSION 1 | SESSION 2 | SESSION 3 |
|---|---|---|---|
| ANT CABLE LENGTH | 100 ft | 100 ft | 35 ft |
| POWER SUPPLY | 12 V DC | 12 V DC | 12 V DC |
| WEATHER CONDITIONS | CLEAR, COOL 45° | CLEAR, COOL 40° | CLEAR, COOL 40° |
| MONUMENT TYPE | "C" (SET IN PIER) | ← SAME | ← SAME |
| EXACT STAMPING | PIER 2 1953 | ← " | ← " |
| AGENCY CAST IN DISK | COE | ← " | ← " |

SKETCH OF SITE

SESSION 1 | SESSION 2 | SESSION 3




Describe any abnormalities and/or problems encountered during the survey, include session number, time of occurance and duration.

THE ANTENNA WAS MOUNTED DIRECTLY OVER PIER 2. WITH NO TRIPOD USED.
ANTENNA HEIGHT WAS MEASURED VERTICALLY FROM - GROUND PLANE TO BRASS DISK.

PAGE 2

b. Back

**Figure D-5. (Concluded)**

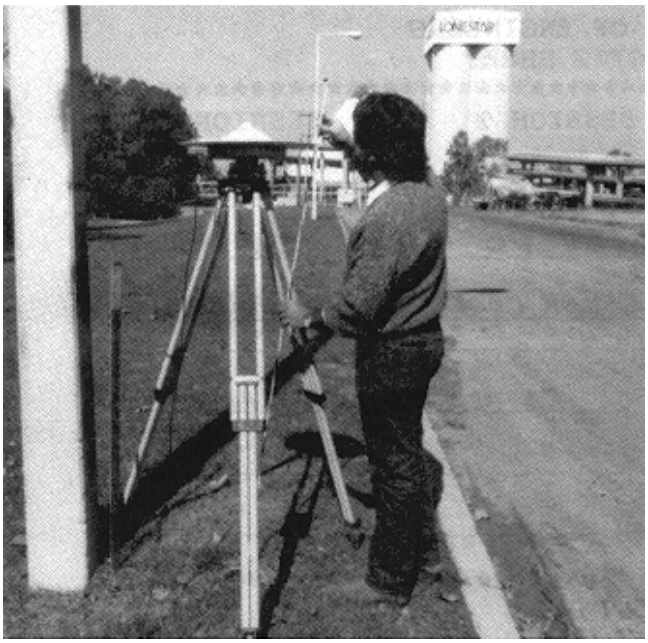


**Figure D-6. Antenna height measurement**

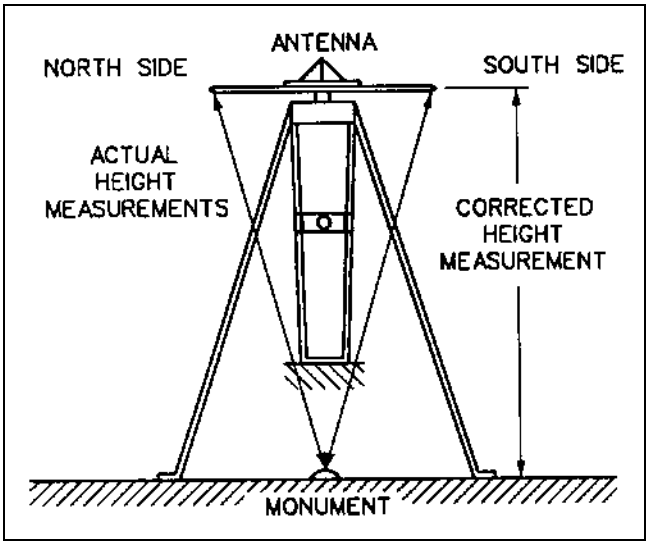



**Figure D-7. Diagram of antenna setup**

observation data were processed in accordance with manufacturer's guidelines. (See Chapter 10 for further discussion on post-processing.)

(1) An examination of the results reveals the following, which are produced in one form or another in other manufacturer's solution file formats:

(a) Listing of the file name.

(b) Types of solutions (single, double, or triple difference).

(c) Satellite availability during the survey for each station occupied.

(d) Ephemeris file used for solution formulation.

(e) Type of satellite selection (manual or automatic).

(f) Elevation mask.

(g) Minimum number of satellites used.

(h) Meteorological data (pressure, temperature, humidity).

(i) Session time (date, time).

(j) Data logging time (start, stop).

(k) Station information:

- Location (latitude, longitude)
- Receiver serial number used
- Antenna serial number used
- ID number
- Antenna height

(l) RMS.

(m) Solution files:

- $\triangle x$, $\triangle y$, $\triangle z$ between stations
- Slope distance between stations
- $\triangle$latitude, $\triangle$longitude between stations
- Distance between stations
- $\triangle$height

(n) Epoch intervals.

(o) Number of epochs.

(2) The triple difference, double difference float, and double difference fix TRIMBLE solutions of the baseline reductions for 2014->2002 are shown annotated with the above conventions (a - o) provided as an explanation.

*c.* In general, all GPS manufacturer data reduction software programs produce a summary of results once data have been reduced and a baseline formulated.

*d.* The listing of the baseline formulations for line 2014 to 2002 follows in Figure D-8, as reproduced from the TRIMBLE Navigation TRIMVEC solution file.

*e.* Although the TRIMBLE summary solution file does specify that the integers were found, the RMS is OK, and FIXED solution is recommended, an analysis of the output prior to this conclusion in accordance with Chapter 10 would have revealed the following:

(1) With a baseline distance of 7,000 m for the formulated baseline (baseline 1402) and from Table 10-1, the RMS must be less than [(0.02 + (0.004*d))]. Using the equation [(0.02 + (0.004/d))] from Table 10-1 with a d (distance) equal to 7 km, the equation is [(0.02 + (0.004*7))] and the RMS is approximately equal to 0.048. Therefore, the RMS is acceptable.

(2) With a baseline distance of 7,000 m for the formulated baseline (baseline 1,402) and from Table 10-1, the quality factor ratio must be more than 3. The fixed solution factor from the summary solution file is 18.9. Therefore, the fixed solution quality factor is acceptable.

(3) From Table 10-1, with a baseline length of 7 km for baseline 1402 (between 0 and 20 km), an acceptable RMS (small), an acceptable quality factor ratio (large), and an integer solution, the fixed solution should be acceptable.

*f.* All other formulated baselines for this survey were found to be acceptable.

## D-4. Loop Closure

An approximate loop closure was done by following the procedures detailed in Chapter 10. The resulting calculations would proceed as shown in the following computation:

*a*. Follow Figure D-9, holding 2013 as the starting point.

*b*. Formulate a table similar to Table 10-3 (see page D-25), where all values are taken from the GPS post-processed baseline formulations:

*c*. Sum up the △x, △y, △z, and distance components:

$\sum\triangle$x components = △x(2013->2014) + △x(2014->2002)
+ △x(2002->2006) + △x(2006->2001)
+ △x(2001->2013)
= -3,367.429 + 3,799.005 + 953.294
+ (-666.617) + (-718.244)

= 0.009

$\sum\triangle$y components = △y(2013->2014) + △y(2014->2002)
+ △y(2002->2006) + △y(2006->2001)
+ △y(2001->2013)
= -7,891.019 + 2,554.018
+ (-748.319) + 1,441.548 + 4,643.775

= 0.003

$\sum\triangle$z components = △z(2013->2014) + △z(2014->2002)
+ △z(2002->2006) + △z(2006->2001)
+ △z(2001->2013)
= -10,410.673 + 5,296.798
+ (-16.709) + 908.280 + 4,222.288

= -0.016

$\sum$Distances = (2013->2014) + (2014->2002)
+ (2002-2006) + (2006->2001)
+ (2001->2013)
= 13,490.362 + 7,000.823 + 1,212.035
+ 1,829.593 + 6,317.297

= 29,850.110

*d.* From Equation 10-1:

$$M = \sqrt{(0.009)^2 + (0.003)^2 + (-0.016)^2} \quad \text{(D-2)}$$

$$= \sqrt{(0.000081) + (0.000009) + (0.000256)} \quad \text{(D-3)}$$

= 0.018601075 or 0.0186

Therefore, misclosure is approximately 0.0186 in., 29,850.110 m, or 1 part in 1,600,000.

## D-5. Final Adjustment

The program used for final adjustment of the Ukiah survey was the GEOLAB program. For an in-depth technical discussion on GEOLAB, refer to the literature accompanying the GEOLAB software package. The following discussion on the GEOLAB adjustment of the Ukiah survey highlights some of the criteria used in the adjustment of a horizontal survey.

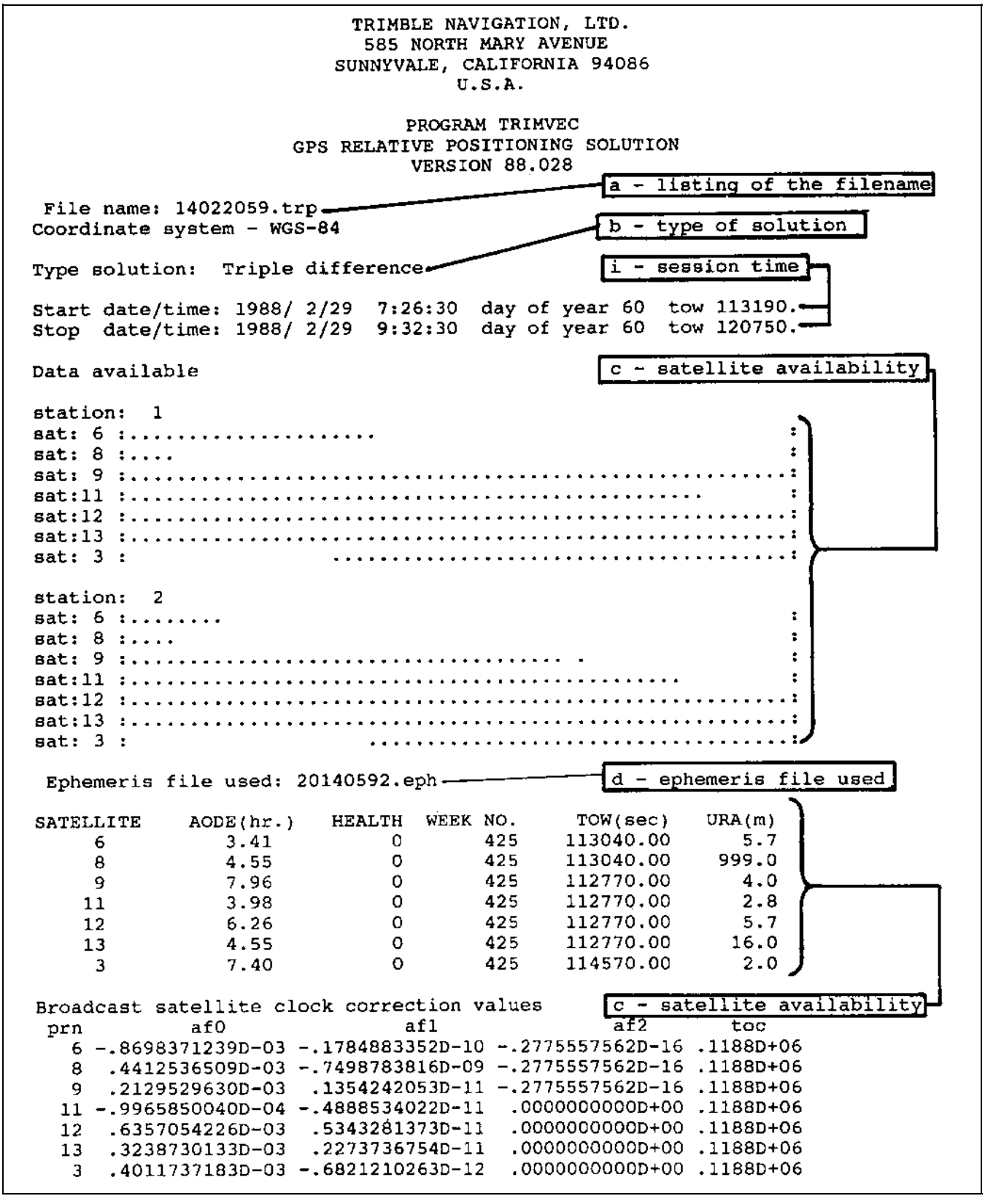



**Figure D-8. TRIMBLE solution file (Ukiah) (Sheet 1 of 13)**

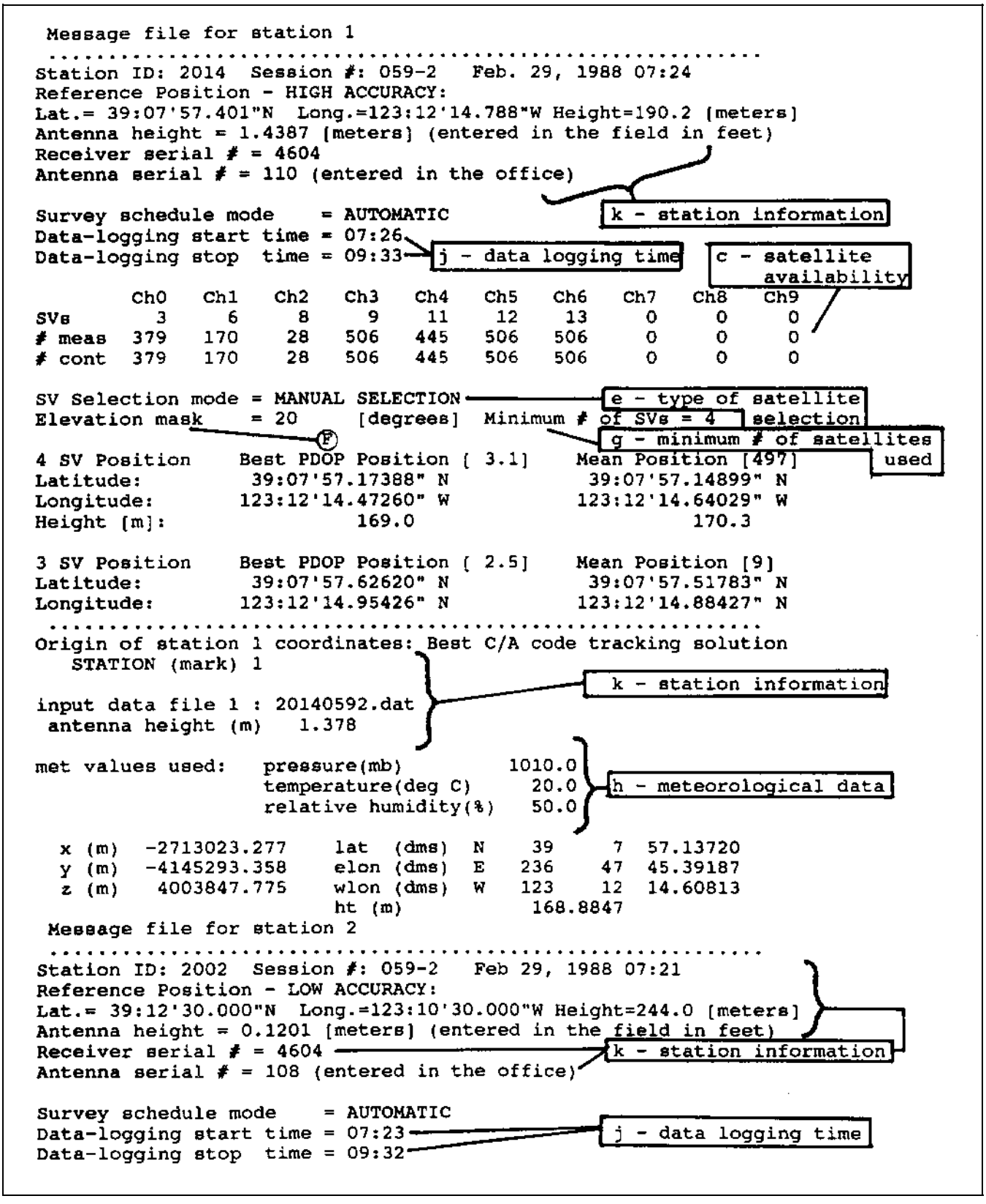



Figure D-8. (Sheet 2 of 13)

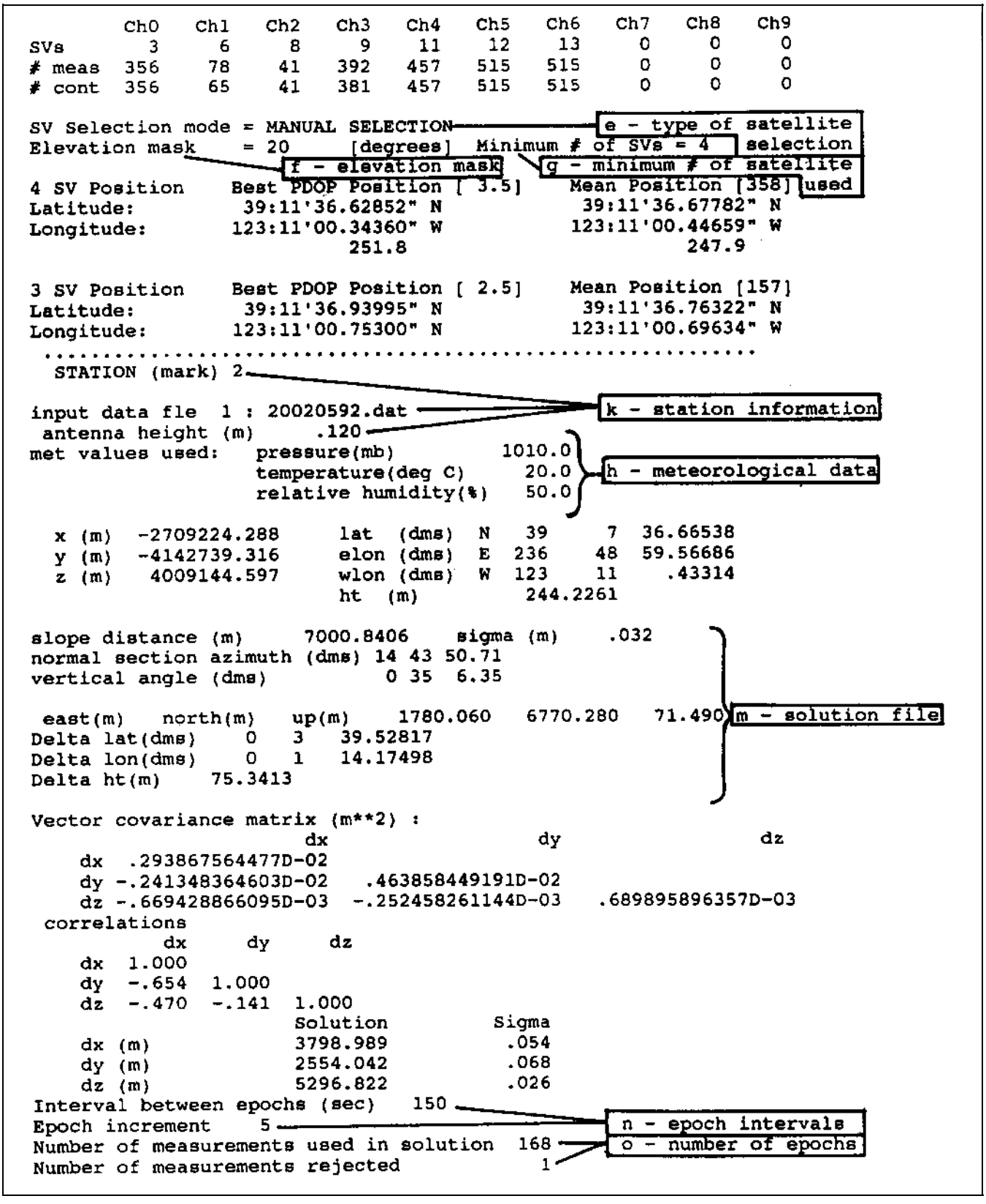



Figure D-8. (Sheet 3 of 13)

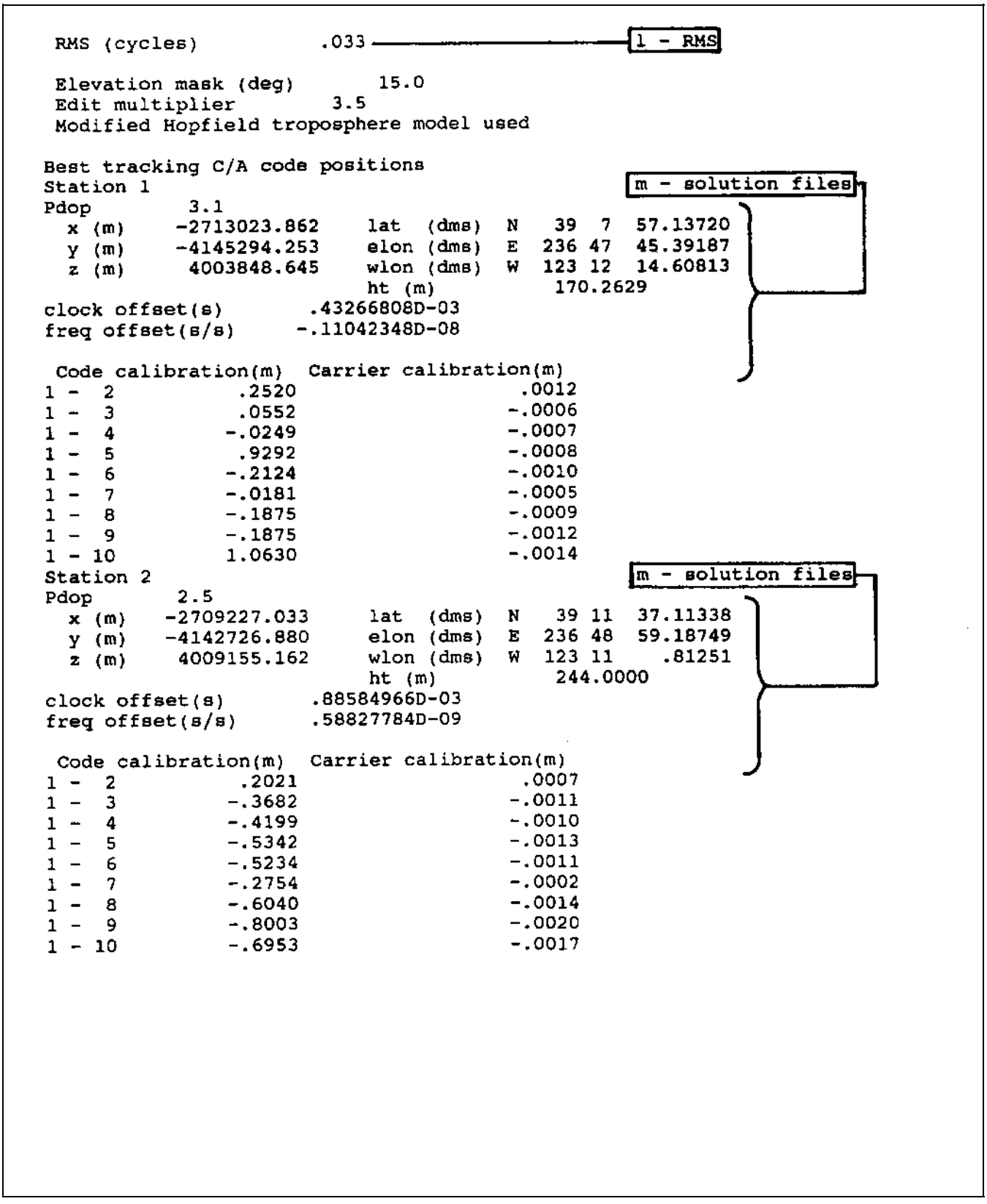



**Figure D-8. (Sheet 4 of 13)**

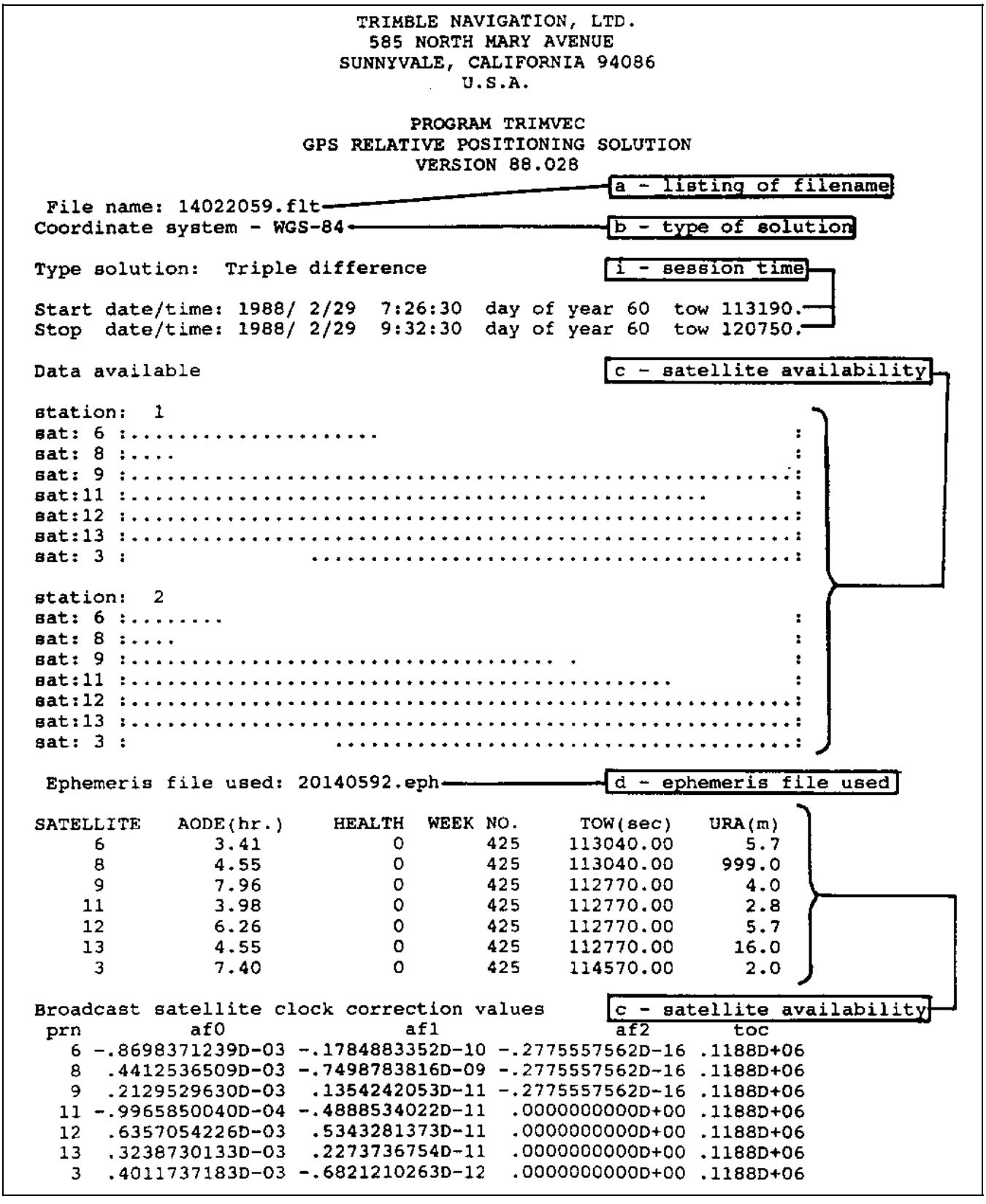



Figure D-8. (Sheet 5 of 13)

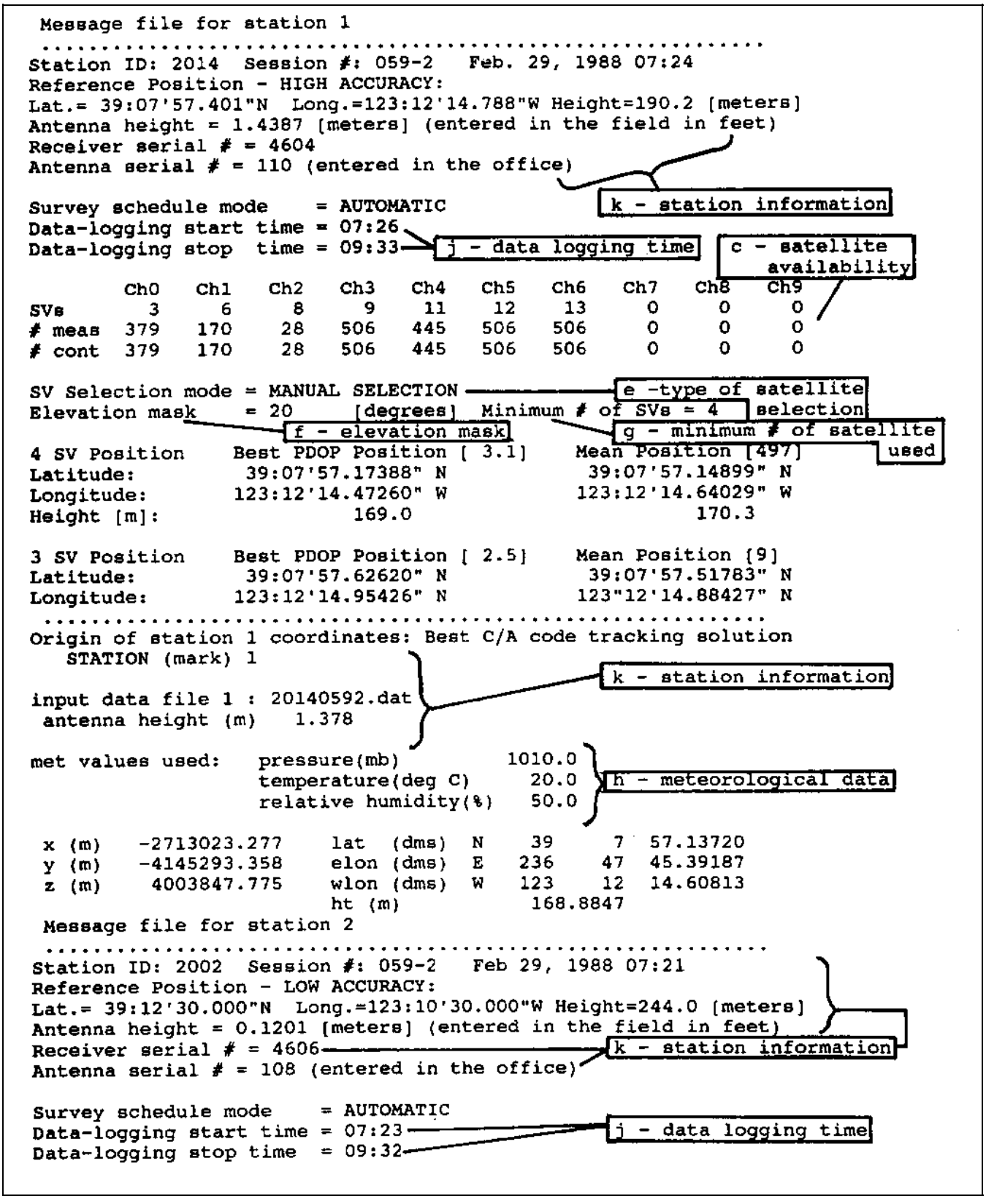



Figure D-8. (Sheet 6 of 13)

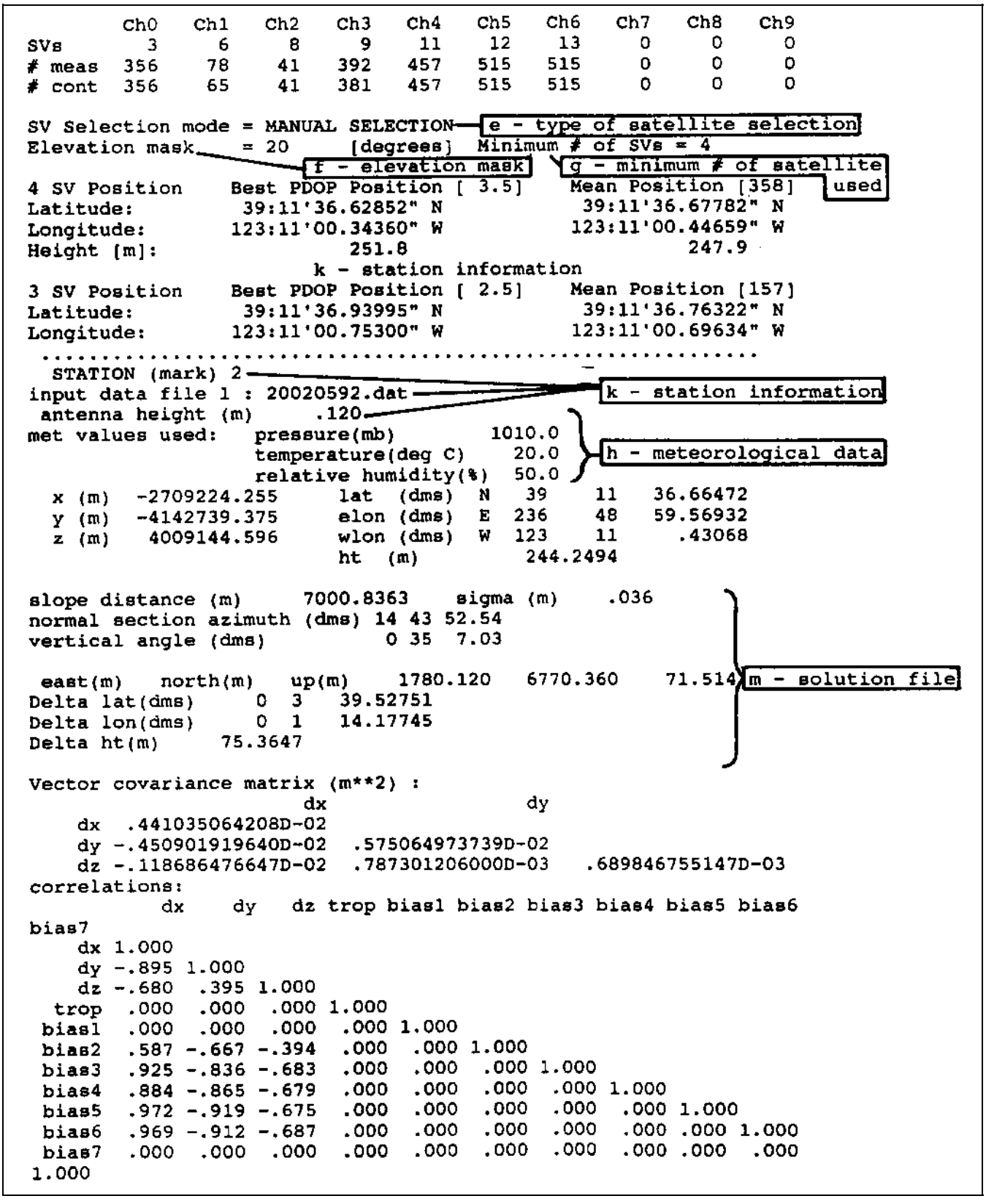
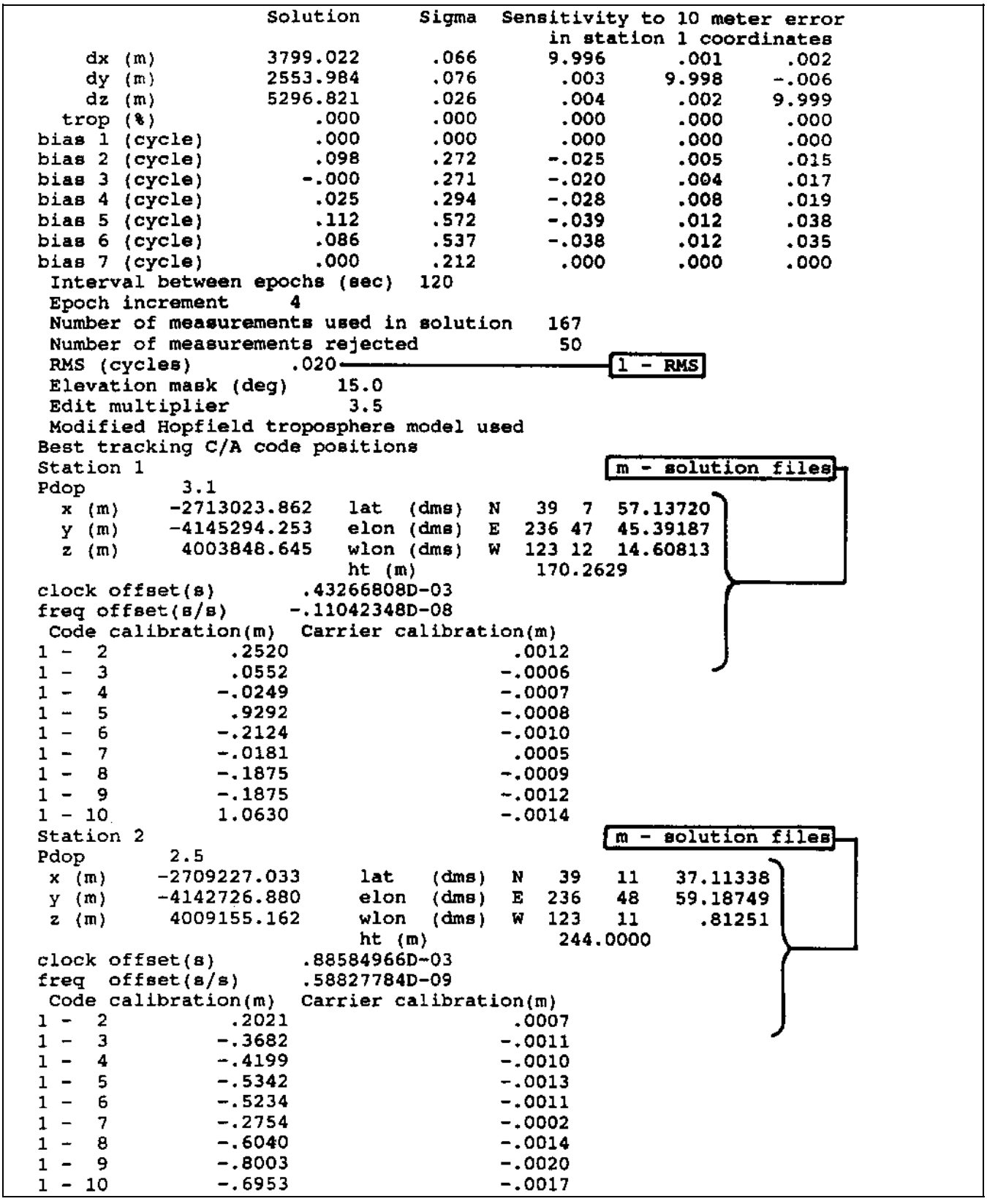



Figure D-8. (Sheet 7 of 13)



```
                    Solution      Sigma  Sensitivity to 10 meter error
                                             in station 1 coordinates
     dx (m)          3799.022       .066       9.996       .001       .002
     dy (m)          2553.984       .076        .003      9.998      -.006
     dz (m)          5296.821       .026        .004       .002      9.999
   trop (%)              .000       .000        .000       .000       .000
bias 1 (cycle)           .000       .000        .000       .000       .000
bias 2 (cycle)           .098       .272       -.025       .005       .015
bias 3 (cycle)          -.000       .271       -.020       .004       .017
bias 4 (cycle)           .025       .294       -.028       .008       .019
bias 5 (cycle)           .112       .572       -.039       .012       .038
bias 6 (cycle)           .086       .537       -.038       .012       .035
bias 7 (cycle)           .000       .212        .000       .000       .000
 Interval between epochs (sec)  120
 Epoch increment     4
 Number of measurements used in solution   167
 Number of measurements rejected            50
 RMS (cycles)         .020 ---------------------- 1 - RMS
 Elevation mask (deg)    15.0
 Edit multiplier          3.5
 Modified Hopfield troposphere model used
Best tracking C/A code positions
Station 1                                              m - solution files
Pdop         3.1
  x (m)    -2713023.862   lat  (dms)  N   39  7  57.13720
  y (m)    -4145294.253   elon (dms)  E  236 47  45.39187
  z (m)     4003848.645   wlon (dms)  W  123 12  14.60813
                          ht (m)          170.2629
clock offset(s)        .43266808D-03
freq offset(s/s)      -.11042348D-08
 Code calibration(m)  Carrier calibration(m)
1 -  2          .2520                    .0012
1 -  3          .0552                   -.0006
1 -  4         -.0249                   -.0007
1 -  5          .9292                   -.0008
1 -  6         -.2124                   -.0010
1 -  7         -.0181                    .0005
1 -  8         -.1875                   -.0009
1 -  9         -.1875                   -.0012
1 - 10         1.0630                   -.0014
Station 2                                              m - solution files
Pdop         2.5
 x (m)    -2709227.033     lat  (dms)  N   39   11   37.11338
 y (m)    -4142726.880     elon (dms)  E  236   48   59.18749
 z (m)     4009155.162     wlon (dms)  W  123   11     .81251
                           ht (m)          244.0000
clock offset(s)        .88584966D-03
freq  offset(s/s)      .58827784D-09
 Code calibration(m)  Carrier calibration(m)
1 -  2          .2021                    .0007
1 -  3         -.3682                   -.0011
1 -  4         -.4199                   -.0010
1 -  5         -.5342                   -.0013
1 -  6         -.5234                   -.0011
1 -  7         -.2754                   -.0002
1 -  8         -.6040                   -.0014
1 -  9         -.8003                   -.0020
1 - 10         -.6953                   -.0017
```

**Figure D-8. (Sheet 8 of 13)**

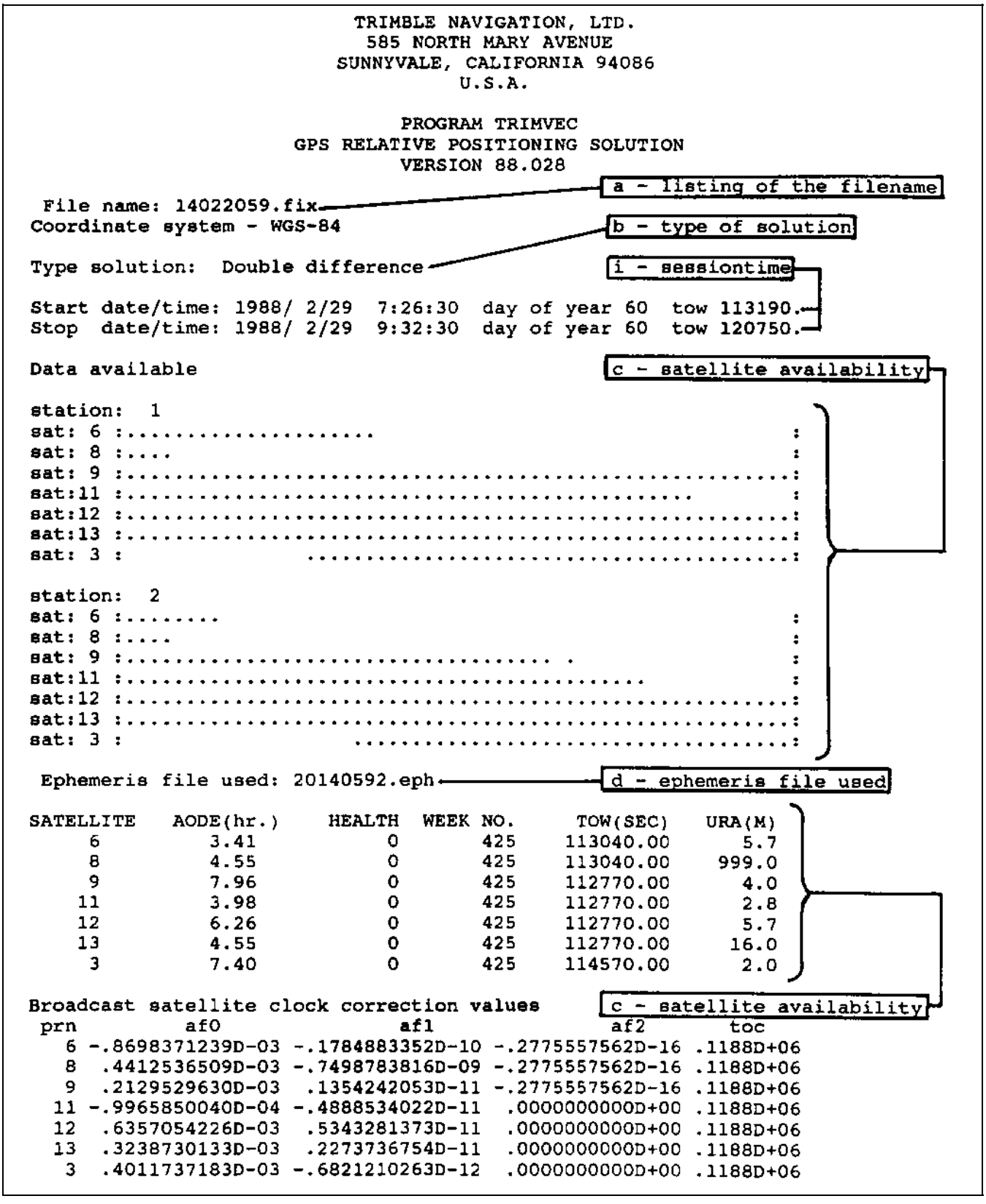



Figure D-8. (Sheet 9 of 13)

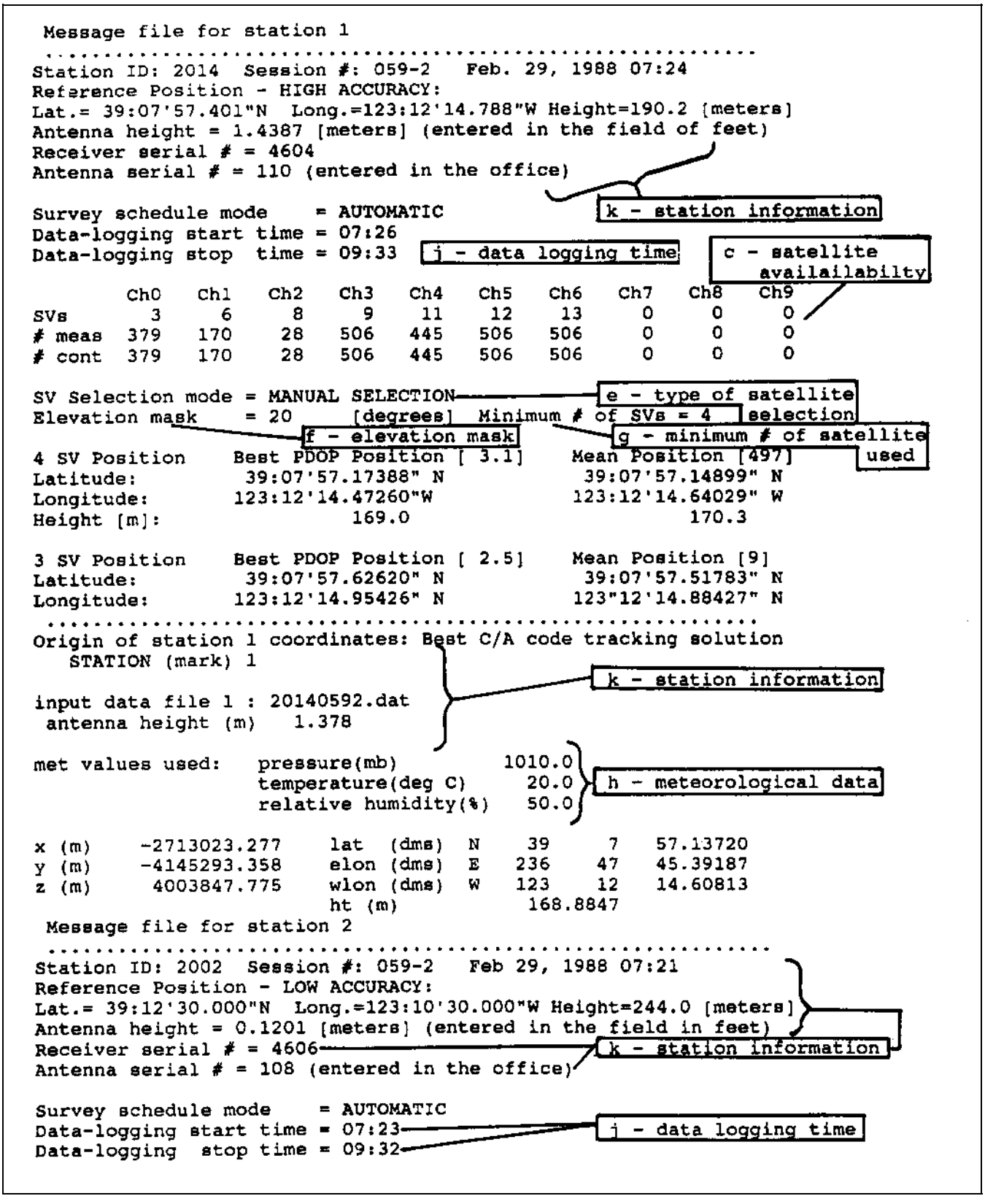



Figure D-8. (Sheet 10 of 13)

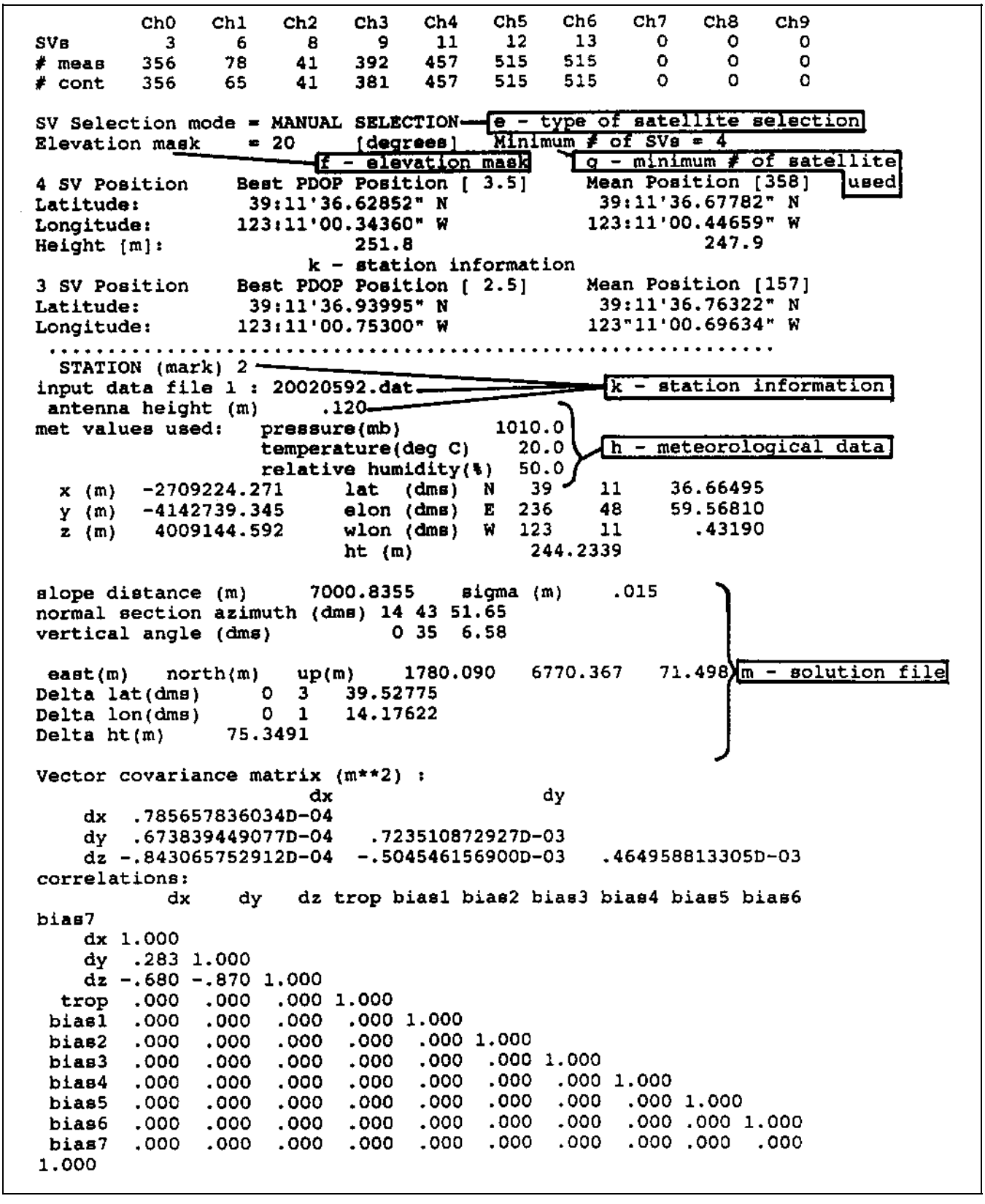
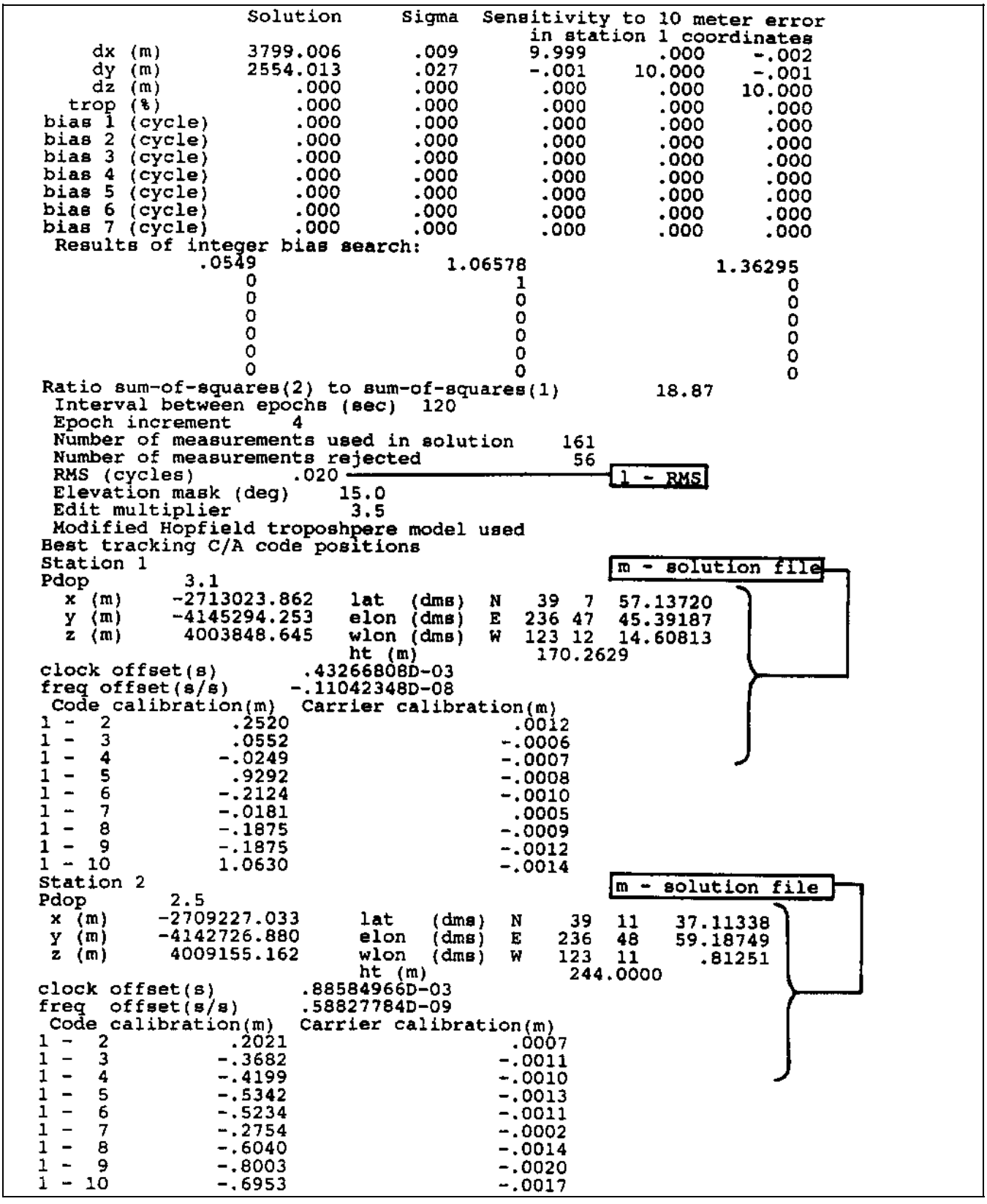



Figure D-8. (Sheet 11 of 13)



```
                    Solution      Sigma  Sensitivity to 10 meter error
                                             in station 1 coordinates
     dx (m)         3799.006       .009       9.999       .000      -.002
     dy (m)         2554.013       .027       -.001     10.000      -.001
     dz (m)             .000       .000        .000       .000    10.000
   trop (%)             .000       .000        .000       .000      .000
bias 1 (cycle)          .000       .000        .000       .000      .000
bias 2 (cycle)          .000       .000        .000       .000      .000
bias 3 (cycle)          .000       .000        .000       .000      .000
bias 4 (cycle)          .000       .000        .000       .000      .000
bias 5 (cycle)          .000       .000        .000       .000      .000
bias 6 (cycle)          .000       .000        .000       .000      .000
bias 7 (cycle)          .000       .000        .000       .000      .000
 Results of integer bias search:
              .0549                    1.06578                  1.36295
                 0                          1                        0
                 0                          0                        0
                 0                          0                        0
                 0                          0                        0
                 0                          0                        0
                 0                          0                        0
Ratio sum-of-squares(2) to sum-of-squares(1)          18.87
 Interval between epochs (sec)  120
 Epoch increment     4
 Number of measurements used in solution     161
 Number of measurements rejected              56
 RMS (cycles)          .020 ------------------------- 1 - RMS
 Elevation mask (deg)    15.0
 Edit multiplier          3.5
 Modified Hopfield troposhpere model used
Best tracking C/A code positions
Station 1                                                  m - solution file
Pdop         3.1
  x (m)     -2713023.862   lat  (dms)  N   39  7  57.13720
  y (m)     -4145294.253   elon (dms)  E  236 47  45.39187
  z (m)      4003848.645   wlon (dms)  W  123 12  14.60813
                           ht (m)          170.2629
clock offset(s)        .43266808D-03
freq offset(s/s)      -.11042348D-08
 Code calibration(m)  Carrier calibration(m)
1 -  2           .2520                    .0012
1 -  3           .0552                   -.0006
1 -  4          -.0249                   -.0007
1 -  5           .9292                   -.0008
1 -  6          -.2124                   -.0010
1 -  7          -.0181                    .0005
1 -  8          -.1875                   -.0009
1 -  9          -.1875                   -.0012
1 - 10          1.0630                   -.0014
Station 2                                                  m - solution file
Pdop         2.5
 x (m)     -2709227.033     lat   (dms)  N    39  11   37.11338
 y (m)     -4142726.880     elon  (dms)  E   236  48   59.18749
 z (m)      4009155.162     wlon  (dms)  W   123  11     .81251
                           ht (m)          244.0000
clock offset(s)        .88584966D-03
freq  offset(s/s)      .58827784D-09
 Code calibration(m)  Carrier calibration(m)
1 -  2           .2021                    .0007
1 -  3          -.3682                   -.0011
1 -  4          -.4199                   -.0010
1 -  5          -.5342                   -.0013
1 -  6          -.5234                   -.0011
1 -  7          -.2754                   -.0002
1 -  8          -.6040                   -.0014
1 -  9          -.8003                   -.0020
1 - 10          -.6953                   -.0017
```

**Figure D-8. (Sheet 12 of 13)**

```
------------------------------------------------------------------
TRIMVEC GPS RELATIVE POSITIONING SOLUTION SUMMARY: VERSION 88.028

SOLUTION OUTPUT FILE: a:14022059.fix

STATION 1:  Station ID: 2014  Session No.: 059-2  Feb 29,1988
07:24
Data-logging start time = 07:26    Data-logging stop time = 09:33

STATION 2:  Station ID: 2002  Session #: 059-2  Feb 29,1988 07:21
Data-logging start time = 07:23    Data-logging stop time = 09:32

STATION COORDINATES:

Sta       Ant (m)      Latitude            Longitude          Hgt (m)
 1          1.378   39:07'57.13720" N  123:12'14.60813" W  168.885
 2 [TRP]    0.120   39:11'36.66538" N  123:11'00.43314" W  244.226
 2 [FLT]    0.120   39:11'36.66472" N  123:11'00.43068" W  244.249
 2 [FIX]    0.120   39:11'36.66495" N  123:11'00.43190" W  244.234

Origin of station 1 coordinates : Best C/A code tracking solution

 SOLUTION SUMMARY:

Solution      dx (m)        dy (m)     dz(m)      dh (m)      RDOP
TRIPLE      3798.989      2554.042   5296.822    75.341      n/a
FLOAT       3799.022      2553.984   5296.821    75.365      n/a
FIXED       3799.006      2554.013   5296.817    75.349      n/a
FLT-FIX        0.016        -0.029      0.004     0.016

Solution Slope (m)  sig  Epochs/Rejected  Epoch int     Epoch inc
TRIPLE   7000.8406 [0.032]  168/  1       150 (secs)    5 (epochs)
FLOAT    7000.8363 [0.036]  167/ 50       120 (secs)    4 (epochs)
FIXED    7000.8355 [0.015]  161/ 56       120 (secs)    4 (epochs)

Fixed solution quality factor:   18.9
Fixed solution rms:            0.020 (cycles)
Maximum float - fixed delta:     2.0 (cm)

Integers found, RMS is OK, FIXED solution recommended.
------------------------------------------------------------------
```

Figure D-8. (Sheet 13 of 13)

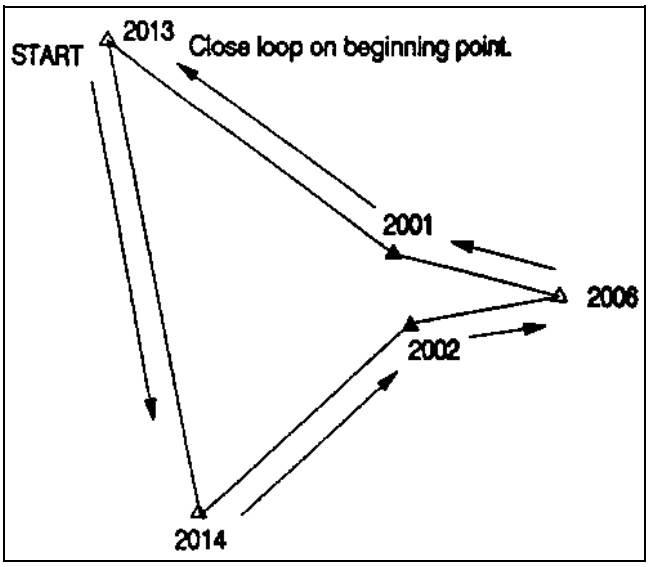



**Figure D-9. Loop closure (Ukiah)**

*a.* The input data file for a GEOLAB adjustment is called an "IOB" file. An IOB file can be created using a text editor program or with a GEOLAB option called "GPS Environment." An IOB file is specific to the GEOLAB adjustment software and may or may not be required by other least-square adjustment software (refer to Chapter 11 or the owner's manual). The GEOLAB Environment option takes GPS baseline solution files developed by most GPS manufacturers and automatically sets up an IOB file for adjustment.

*b.* The IOB input file generally consists of the following information:

(1) *Top line.* Title Record - usually a project name and an adjustment number.

(2) *Second line.* Options Record - this record specifies which GEOLAB options are to be activated for processing.

(3) *Third line.* Ellipsoid Specification Record - Prints ellipsoid parameters chosen in the Options Record or as chosen by the user.

(4) *Station information section.* All stations must have their coordinates defined here. The coordinates must be given as ellipsoidal latitude, longitude, and orthometric height, or as Cartesian coordinates. In this section, stations are either held fixed or are to be adjusted. If stations are not held fixed, estimated coordinates are input.

(5) *Auxiliary parameter definition record.* The auxiliary parameter group definition record is optional, but can be used if GEOLAB is to solve for various scale, orientation, translation, or constant parameters. In the sample GEOLAB input, enough vertical and horizontal control is held fixed to solve for SCALE and ROTATION. Rotation is about the Cartesian X-axis, Y-axis, and Z-axis.

(6) *Observation records section.* In the example GEOLAB input file, only GPS observations are entered. Each baseline is entered separately with the station name and Cartesian coordinate differences between the stations, which is the computed baseline. These can also be entered as $\triangle x=0$, $\triangle y=0$, $\triangle z=0$, for station 1 and the 3D

| **Baseline** | **△ x, m** | **△ y, m** | **△ z, m** | **Distance, m** |
|---|---|---|---|---|
| 13142059.FIX<br>2013 -> 2014 | -3,367.429 | -7,891.019 | -10,410.673 | 13,490.362 |
| 14021059.FIX<br>2014 -> 2002 | 3,799.005 | 2,554.018 | 5,296.798 | 7,000.823 |
| 02053056.FIX<br>2002 -> 2006 | 953.294 | -748.319 | -16.709 | 1,212.035 |
| 06013056.FIX<br>2006 -> 2001 | -666.617 | 1,441.548 | 908.280 | 1,829.593 |
| 01132059.FIX<br>2001 -> 2013 | -718.244 | 4,643.775 | 4,222.288 | 6,317.297 |

baseline for station 2. For example, baseline 1 would be entered as:

| STATION | | △x | △y | △z |
|---|---|---|---|---|
| 92 | 2001 | 0.000 | 0.000 | 0.000 |
| 92 | 2006 | -666.617 | 1,441.548 | 908.280 |

The correlation matrix elements from the baseline solution are also entered and the last line of the observation record is the standard deviation for △x, △y, and △z.

*c.* The following figure (Figure D-10) taken from a GEOLAB input is annotated with the convention above.

*d.* Once an IOB file containing parameters necessary to perform an adjustment has been completed, the adjustment can begin. The first step is to select the baselines needed for the adjustment. The baselines chosen must have been processed adequately, as detailed in Chapter 10, or as recommended by the GPS manufacturer.

*e.* The example IOB file shown in Figure D-10 was adjusted as shown in Figure D-11. Figure D-11 has been annotated for a general discussion of the results.

*f.* For the first adjustment (Figure D-11), one point was held fixed in 3D, producing a free adjustment (refer to Chapter 10 for further detail). A free adjustment checks the internal consistency of a GPS survey.

*g.* A second adjustment (not shown) can be made to check the existing network if these control points are directly tied together with GPS baselines. To do this with GEOLAB, the user must set up an IOB file with only the fixed control and the respective baselines connecting them. Hold fixed all control except one point, then adjust. Next, fix that control point and free one of the others, and keep repeating this procedure until all control points have been allowed to be checked against their true position. If the position of one control point is "bad," that point can generally be omitted from the subsequent constrained adjustment or allowed to adjust with the other points.

*h.* A final constrained adjustment (Figure D-12) should hold fixed all good horizontal and vertical control. Adjust and check the output as detailed in Chapter 11.

## D-6. Check of the Final Adjustment

After each adjustment was run, the 2D and 1D station (absolute) error ellipse for each adjusted point was reviewed (for further discussion on error ellipses and adjustments, refer to Chapter 11). These are listed as major semi-axis, minor semi-axis, major azimuth, and vertical (as shown on page 15 of the free adjustment and page 16 of the constrained adjustment).[1] The size of the error ellipses listed in this portion of the GEOLAB adjustment are an indication of the internal consistency of the GPS survey. The smaller the size of the ellipse, the better the survey. The size of the ellipse will also generally become larger as the project size increases. In the constrained adjustment shown, the major semi-axis and minor semi-axis are of the millimeter level (0.0066 and 0.0048 mm for 2001 and 0.0062 and 0.0044 mm for 2002, respectively) - which is acceptable.

*a.* The 2D and 1D relative error ellipses and line accuracies (i.e., precision) between survey points were checked. These are listed as major semi-axis, minor semi-axis, major azimuth, and vertical, spatial distance, and precision (as shown on page 16 of the free adjustment and page 17 of the constrained adjustment). When checking these values, one should remember they are relative values. The relativity of points used in the adjustment can sometimes produce deceptive values, higher major semi-axis and minor semi-axis values: this may occur between points that are close together, but have not been tied together by a baseline. Because of the possibility of the production of deceptive results, the user must take special care when reviewing these values. In the constrained adjustment shown, the major semi-axis and minor semi-axis are of the millimeter level (0.0045 and 0.0036 for the baseline 2001->2002). The project precision in parts per million (PPM) is also listed in this portion of the adjustment and should be checked.

*b.* The histograms in the GEOLAB adjustments were reviewed. The histogram is a visual representation of the standardized (normalized) residuals. The histogram shows whether the residuals are symmetrical about the mean residual, the total spread of values of the residuals, the frequencies of the different values, and how peaked or how flat the distribution of the residuals may be. A generally good looking histogram has data that, when graphed, is in the shape of a bell curve.

*c.* The free adjustment line accuracy precessions shown on page 16 of Figure D-11 are the primary criteria used to evaluate the survey adequacy. The worst precision (4.182 ppm between 2001 and 2013) equates to 1:239,000. This far exceeds the required project accuracy

[1] Note the page numbers listed on the right side of the sheets of Figures D-11 and D-12. Each sheet contains several pages of the GEOLAB adjustments.

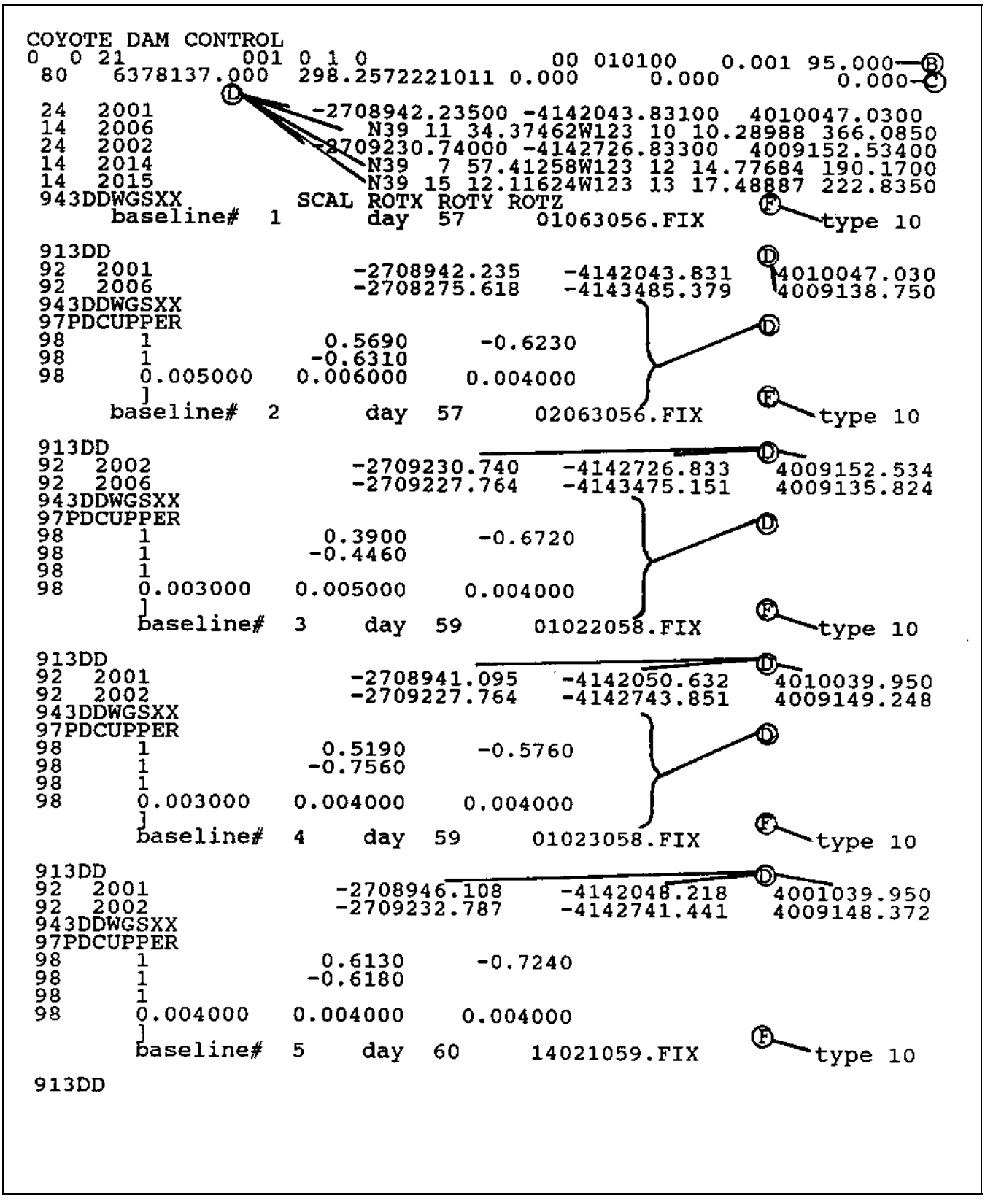



**Figure D-10. GEOLAB input (Ukiah) (Continued)**

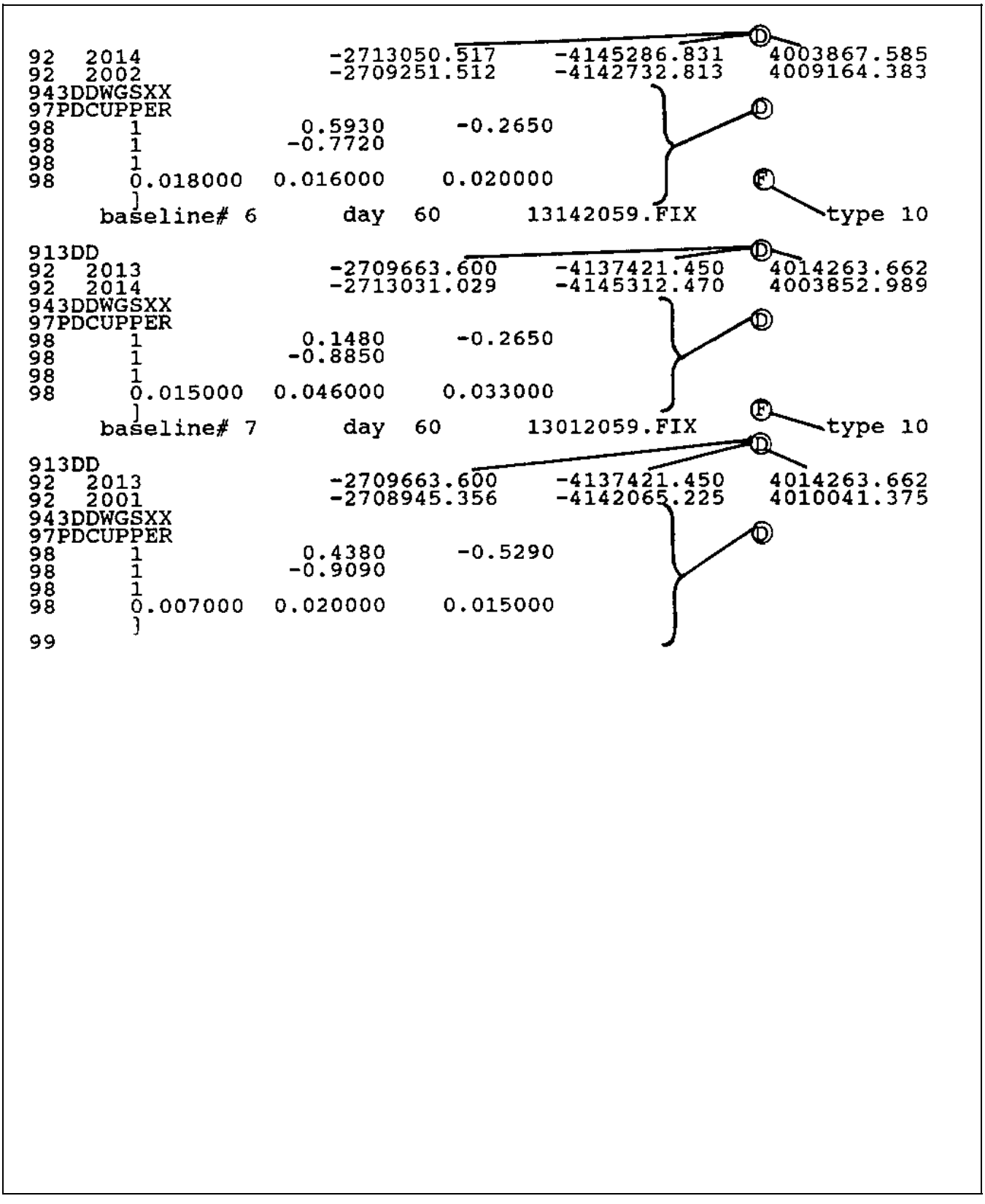
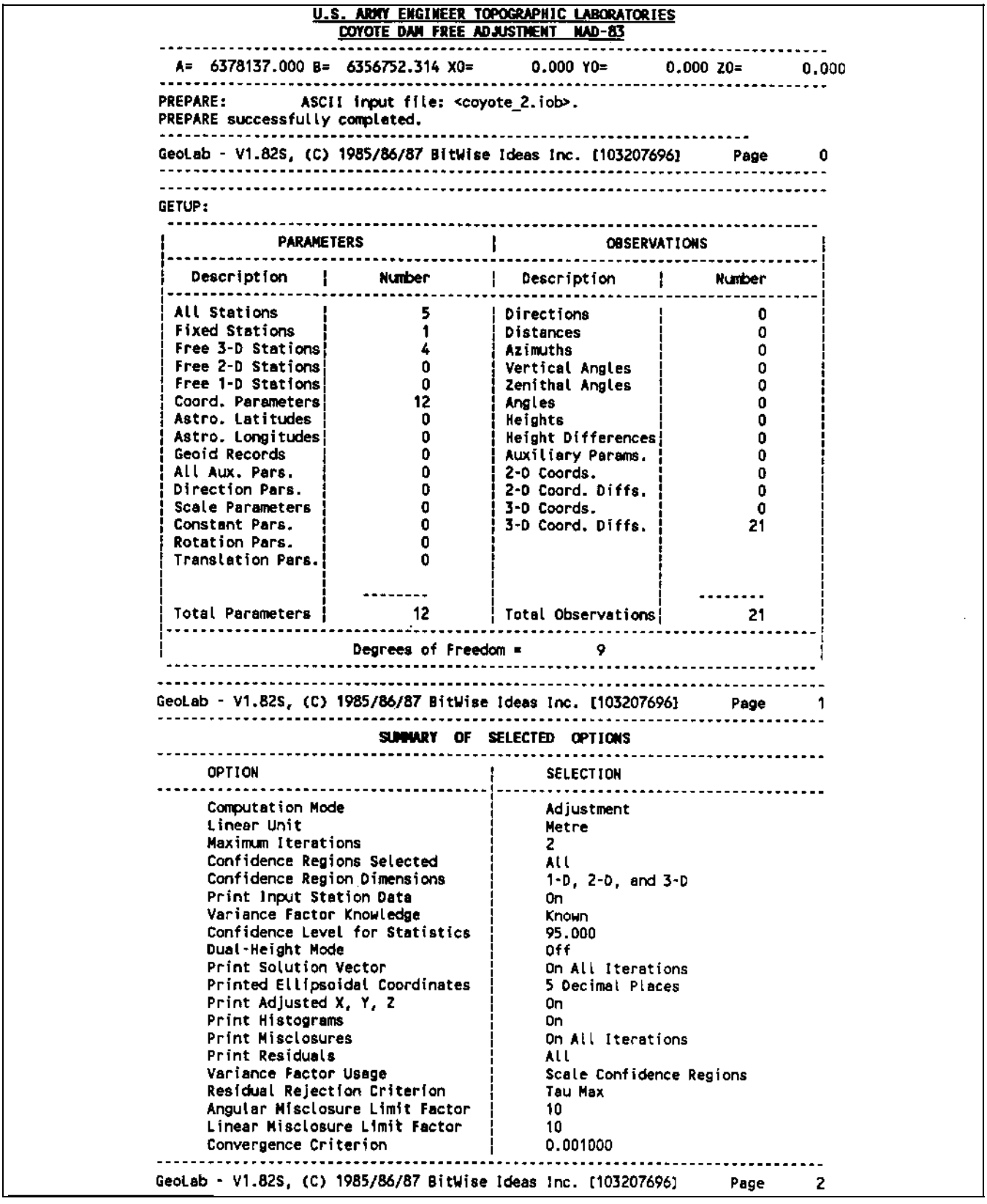



Figure D-10. (Concluded)



U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT NAD-83

A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

PREPARE: ASCII input file: <coyote_2.iob>.
PREPARE successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 0

GETUP:

| PARAMETERS | | OBSERVATIONS | |
|---|---|---|---|
| Description | Number | Description | Number |
| All Stations | 5 | Directions | 0 |
| Fixed Stations | 1 | Distances | 0 |
| Free 3-D Stations | 4 | Azimuths | 0 |
| Free 2-D Stations | 0 | Vertical Angles | 0 |
| Free 1-D Stations | 0 | Zenithal Angles | 0 |
| Coord. Parameters | 12 | Angles | 0 |
| Astro. Latitudes | 0 | Heights | 0 |
| Astro. Longitudes | 0 | Height Differences | 0 |
| Geoid Records | 0 | Auxiliary Params. | 0 |
| All Aux. Pars. | 0 | 2-D Coords. | 0 |
| Direction Pars. | 0 | 2-D Coord. Diffs. | 0 |
| Scale Parameters | 0 | 3-D Coords. | 0 |
| Constant Pars. | 0 | 3-D Coord. Diffs. | 21 |
| Rotation Pars. | 0 | | |
| Translation Pars. | 0 | | |
| Total Parameters | 12 | Total Observations | 21 |

Degrees of Freedom = 9

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 1

SUMMARY OF SELECTED OPTIONS

| OPTION | SELECTION |
|---|---|
| Computation Mode | Adjustment |
| Linear Unit | Metre |
| Maximum Iterations | 2 |
| Confidence Regions Selected | All |
| Confidence Region Dimensions | 1-D, 2-D, and 3-D |
| Print Input Station Data | On |
| Variance Factor Knowledge | Known |
| Confidence Level for Statistics | 95.000 |
| Dual-Height Mode | Off |
| Print Solution Vector | On All Iterations |
| Printed Ellipsoidal Coordinates | 5 Decimal Places |
| Print Adjusted X, Y, Z | On |
| Print Histograms | On |
| Print Misclosures | On All Iterations |
| Print Residuals | All |
| Variance Factor Usage | Scale Confidence Regions |
| Residual Rejection Criterion | Tau Max |
| Angular Misclosure Limit Factor | 10 |
| Linear Misclosure Limit Factor | 10 |
| Convergence Criterion | 0.001000 |

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 2

**Figure D-11. GEOLAB adjustment output (free) (Sheet 1 of 7)**

```
                    U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          COYOTE DAM     FREE ADJUSTMENT
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000
------------------------------------------------------------------------------
CODE IDENT.    DESCRIPTOR      INITIAL VALUES
---- ------    ----------      --------------

 14  2006
                ELLIPSOIDAL :   39 11 34.37462 -123 10 10.28988        336.0850
                ASTRONOMIC  :   39 11 34.37462 -123 10 10.28988        336.0850
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2708280.4788    -4143494.7721    4009147.8933

 24  2001
                ELLIPSOIDAL :   39 12 14.43422 -123 11  6.45941        243.8658
                ASTRONOMIC  :   39 12 14.43422 -123 11  6.45941        243.8658
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2708942.2350    -4142043.8310    4010047.0300

 24  2002
                ELLIPSOIDAL :   39 11 37.00656 -123 11  0.94286        243.8815
                ASTRONOMIC  :   39 11 37.00656 -123 11  0.94286        243.8815
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2709230.7400    -4142726.8330    4009152.5340

 24  2014
                ELLIPSOIDAL :   39  7 57.44196 -123 12 15.70589        188.7219
                ASTRONOMIC  :   39  7 57.44196 -123 12 15.70589        188.7219
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2713050.5170    -4145286.8310    4003867.5850

 24  2013
                ELLIPSOIDAL :   39 15 11.55819 -123 13 17.15396        220.5009
                ASTRONOMIC  :   39 15 11.55819 -123 13 17.15396        220.5009
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2709663.6000    -4137421.4500    4014263.6620
GETUP successfully completed.
------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      3
------------------------------------------------------------------------------
------------------------------------------------------------------------------
FORMEQ: NOTE 6:          Reordering was done.
AT       TO       OBS TYPE              OBSERVATION  APPROX.SIG.   MISCLOSURE
-------- -------- --------------- --------------- ------------ ------------
2001     2006     3-D X-Coord Diff        666.6170       0.0037       -4.8608
2001     2006     3-D Y-Coord Diff      -1441.5480       0.0045       -9.3931
2001     2006     3-D Z-Coord Diff       -908.2800       0.0028        9.1433
2002     2006     3-D X-Coord Diff        953.2950       0.0022       -3.0338
2002     2006     3-D Y-Coord Diff       -748.3180       0.0044      -19.6211
2002     2006     3-D Z-Coord Diff        -16.7100       0.0029       12.0693
2001     2002     3-D X-Coord Diff       -286.6690       0.0024       -1.8360
2001     2002     3-D Y-Coord Diff       -693.2190       0.0026       10.2170
2001     2002     3-D Z-Coord Diff       -891.5890       0.0025       -2.9070
2001     2002     3-D X-Coord Diff       -286.6790       0.0026       -1.8260
2001     2002     3-D Y-Coord Diff       -693.2230       0.0030       10.2210
2001     2002     3-D Z-Coord Diff       -891.5780       0.0026       -2.9180
2014     2002     3-D X-Coord Diff       3799.0050       0.0129       20.7720
2014     2002     3-D Y-Coord Diff       2554.0180       0.0101        5.9800
2014     2002     3-D Z-Coord Diff       5296.7980       0.0113      -11.8490
2013     2014     3-D X-Coord Diff      -3367.4290       0.0142      -19.4880
2013     2014     3-D Y-Coord Diff      -7891.0200       0.0210       25.6390
2013     2014     3-D Z-Coord Diff     -10410.6730       0.0147       14.5960
2013     2001     3-D X-Coord Diff        718.2440       0.0059        3.1210
2013     2001     3-D Y-Coord Diff      -4643.7750       0.0083       21.3940
2013     2001     3-D Z-Coord Diff      -4222.2870       0.0059        5.6550
FORMEQ successfully completed.
------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      4
```

**Figure D-11. (Sheet 2 of 7)**

```
                    U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          COYOTE DAM     FREE ADJUSTMENT
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000

SOLVE:          Solution (Iteration Count = 1):
CODE IDENT.   TYPE                  INITIAL            DX              UPDATED
---- -------- --------- ------------------ ------------- ------------------
 24  2001     LATITUDE     39  12  14.43422       0.01413    39  12  14.44836
 24  2001     LONGITUDE  -123  11   6.45941       0.04476  -123  11   6.41465
 24  2001     HEIGHT              243.86577      13.93969           257.80546

 24  2002     LATITUDE     39  11  37.00656      -0.06729    39  11  36.93927
 24  2002     LONGITUDE  -123  11   0.94286       0.34171  -123  11   0.60115
 24  2002     HEIGHT              243.88154      21.63376           265.51530

 24  2014     LATITUDE     39   7  57.44196      -0.02938    39   7  57.41258
 24  2014     LONGITUDE  -123  12  15.70589       0.92905  -123  12  14.77684
 24  2014     HEIGHT              188.72193       1.44519           190.16712

 24  2013     LATITUDE     39  15  11.55819       0.55805    39  15  12.11624
 24  2013     LONGITUDE  -123  13  17.15396      -0.33491  -123  13  17.48887
 24  2013     HEIGHT              220.50094       2.33476           222.83570
SOLVE successfully completed.
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      5

FORMEQ:         FORMEQ successfully completed.
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      6

SOLVE:          Adjusted Values (Iteration Count = 2):
CODE IDENT.   TYPE                  INITIAL            DX              ADJUSTED
---- -------- --------- ------------------ ------------- ------------------
 14  2006     LATITUDE     39  11  34.37462         FIXED
 14  2006     LONGITUDE  -123  10  10.28988         FIXED
 14  2006     HEIGHT              336.08500         FIXED

 24  2001     LATITUDE     39  12  14.44836      -0.00000    39  12  14.44836
 24  2001     LONGITUDE  -123  11   6.41465      -0.00000  -123  11   6.41465
 24  2001     HEIGHT              257.80546      -0.00000           257.80546

 24  2002     LATITUDE     39  11  36.93927       0.00000    39  11  36.93927
 24  2002     LONGITUDE  -123  11   0.60115      -0.00000  -123  11   0.60115
 24  2002     HEIGHT              265.51530       0.00001           265.51530

 24  2014     LATITUDE     39   7  57.41258      -0.00000    39   7  57.41258
 24  2014     LONGITUDE  -123  12  14.77684      -0.00000  -123  12  14.77684
 24  2014     HEIGHT              190.16712       0.00004           190.16716

 24  2013     LATITUDE     39  15  12.11624      -0.00000    39  15  12.11624
 24  2013     LONGITUDE  -123  13  17.48887      -0.00000  -123  13  17.48887
 24  2013     HEIGHT              222.83570       0.00003           222.83573
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      7

                    Adjusted Cartesian Coordinates:
CODE IDENT.          X-COORDINATE       Y-COORDINATE       Z-COORDINATE
---- -------- ------------------ ------------------ ------------------
 24  2001          -2708947.0978      -4142053.2284      4010056.1788
 24  2002          -2709233.7714      -4142746.4510      4009164.5970
 24  2014          -2713032.7730      -4145300.4675      4003867.7943
 24  2013          -2709665.3421      -4137409.4529      4014278.4662
SOLVE successfully completed.
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      8
```

Figure D-11. (Sheet 3 of 7)

```
                    U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          COYOTE DAM     FREE ADJUSTMENT
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000

INVERT:          INVERT successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      9

RESID:
STATION    3-D COORD DIFFS    STD.DEV.    RESIDUAL    STD.DEV.   STAN.RES.
--------   --------------   ----------  ----------  ----------  ----------
2001          -2708942.2350
              -4142043.8310
               4010047.0300
2006          -2708275.6180      0.0050      0.0020      0.0040      0.4913
              -4143485.3790      0.0060      0.0043      0.0044      0.9722
               4009138.7500      0.0040     -0.0055      0.0026     -2.1131
============================ End of Observation Set ============================
2002          -2709230.7400
              -4142726.8330
               4009152.5340
2006          -2708277.4450      0.0030     -0.0024      0.0015     -1.5684
              -4143475.1510      0.0050     -0.0031      0.0031     -1.0050
               4009135.8240      0.0040      0.0063      0.0026      2.4021
============================ End of Observation Set ============================
2001          -2708941.0950
              -4142050.6320
               4010040.8370
2002          -2709227.7640      0.0030     -0.0046      0.0020     -2.2695
              -4142743.8510      0.0040     -0.0036      0.0031     -1.1723
               4009149.2480      0.0040      0.0072      0.0032      2.2790
============================ End of Observation Set ============================
2001          -2708946.1080
              -4142048.2180
               4010039.9500
2002          -2709232.7870      0.0040      0.0054      0.0033      1.6114
              -4142741.4410      0.0040      0.0004      0.0031      0.1290
               4009148.3720      0.0040     -0.0038      0.0032     -1.1996
============================ End of Observation Set ============================
2014          -2713050.5170
              -4145286.8310
               4003867.5850
2002          -2709251.5120      0.0180     -0.0034      0.0132     -0.2586
              -4142732.8130      0.0160     -0.0015      0.0077     -0.1983
               4009164.3830      0.0200      0.0047      0.0129      0.3661
============================ End of Observation Set ============================
2013          -2709663.6000
              -4137421.4500
               4014263.6620
2014          -2713031.0290      0.0150     -0.0019      0.0092     -0.2019
              -4145312.4700      0.0460      0.0054      0.0407      0.1332
               4003852.9890      0.0330      0.0011      0.0275      0.0389

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     10

RESID:
STATION    3-D COORD DIFFS    STD.DEV.    RESIDUAL    STD.DEV.   STAN.RES.
--------   --------------   ----------  ----------  ----------  ----------
============================ End of Observation Set ============================
2013          -2709663.6000
              -4137421.4500
               4014263.6620
2001          -2708945.3560      0.0070      0.0003      0.0021      0.1596
              -4142065.2250      0.0200     -0.0005      0.0076     -0.0670
               4010041.3750      0.0150     -0.0004      0.0055     -0.0743
============================ End of Observation Set ============================

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     11
```

Figure D-11. (Sheet 4 of 7)

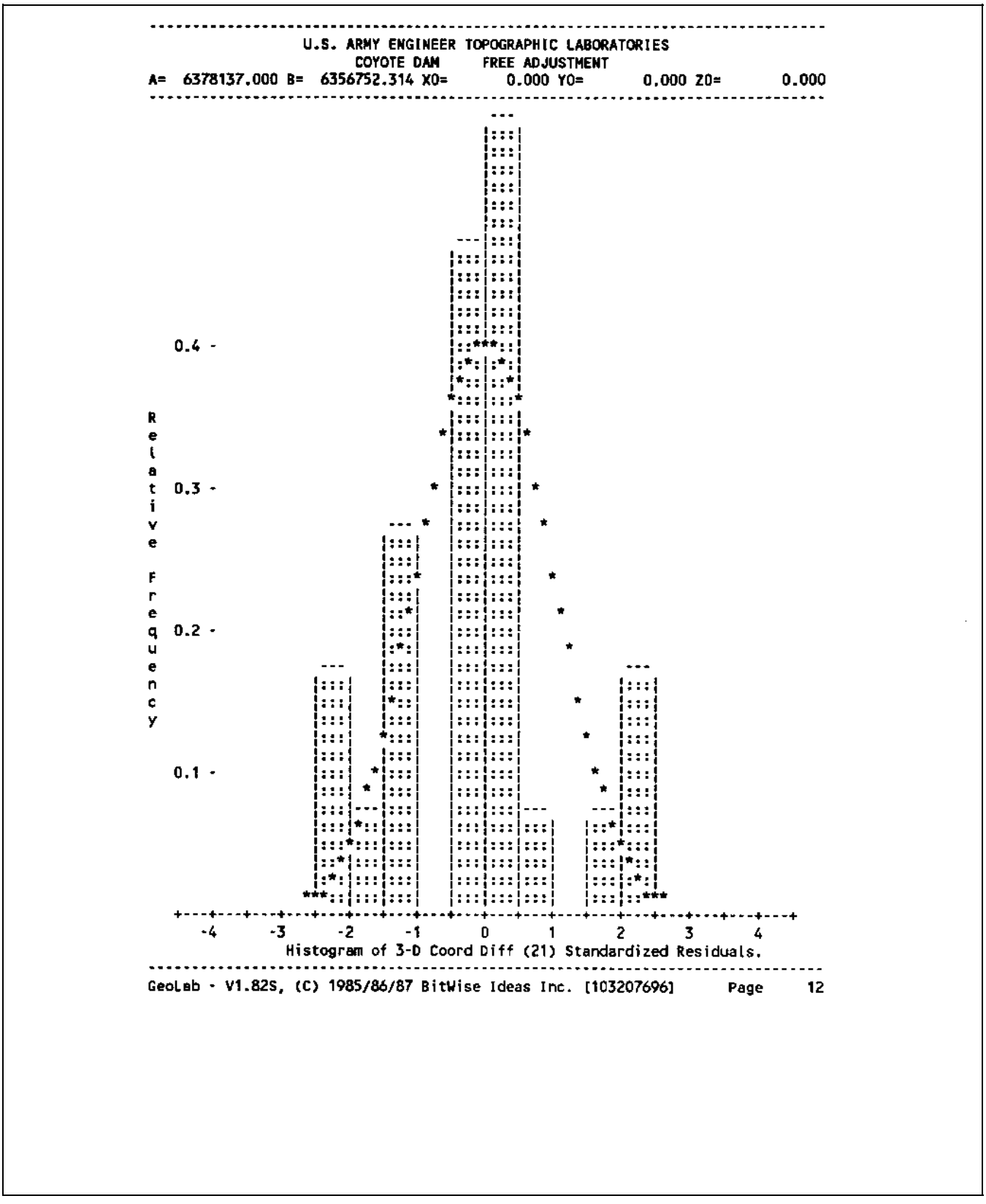



**Figure D-11. (Sheet 5 of 7)**

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

STATISTICS SUMMARY

| | |
|---|---|
| Residual Critical Value Type | Tau Max |
| Residual Critical Value | 2.5985 |
| Convergence Criterion | 0.001000 |
| Final Iteration Counter Value | 2 |
| Confidence Level Used | 95.0000 |
| Number of Flagged Residuals | 0 |
| Estimated Variance Factor | 1.3376 |
| Number of Degrees of Freedom | 9 |

Chi-Square Test on the Variance Factor:

6.3283e-001 < 1.0000 < 4.4579e+000 ?

THE TEST PASSES.

RESID successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 13

ELLIPSE:

NOTE: All confidence regions were computed using the following factors:

| | | |
|---|---|---|
| Variance factor used | = | 1.33757 |
| Estimated variance factor | = | 1.33757 |
| 1-D expansion factor | = | 1.960 |
| 2-D expansion factor | = | 2.448 |
| 3-D expansion factor | = | 2.795 |

Note that, for relative confidence regions, precisions are computed from the ratio of the major semi-axis and the spatial distance between the two stations.

Error ellipses for which all covariance matrix elements were not computed by INVERT, are marked with an asterisk (*).

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 14

ELLIPSE: 2-D AND 1-D STATION CONFIDENCE REGIONS ( 95.000 %):

| IDENT. | MAJOR SEMI-AXIS | MINOR SEMI-AXIS | AZ(MAJ) | VERTICAL |
|---|---|---|---|---|
| 2001 | 0.0073 | 0.0054 | 124.77 | 0.0112 |
| 2002 | 0.0074 | 0.0047 | 130.94 | 0.0106 |
| 2014 | 0.0277 | 0.0211 | 86.20 | 0.0483 |
| 2013 | 0.0273 | 0.0138 | 95.77 | 0.0505 |

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 15

Figure D-11. (Sheet 6 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

ELLIPSE: 2-D AND 1-D RELATIVE STATION CONFIDENCE REGIONS ( 95.000 %):

| FROM | TO | MAJ.SEMI | MIN.SEMI | AZ(MAJ) | VERTICAL | SPATIAL DIST. | PRECISION |
|---|---|---|---|---|---|---|---|
| 2001 | 2002 | 0.0045 | 0.0038 | 105.27 | 0.0082 | 1165.1856 | 3.881 PPM |
| 2001 | 2014 | 0.0272 | 0.0204 | 84.07 | 0.0475 | 8095.2706 | 3.363 PPM |
| 2001 | 2013 | 0.0264 | 0.0125 | 94.67 | 0.0494 | 6317.2966 | 4.182 PPM |
| 2002 | 2014 | 0.0271 | 0.0203 | 83.67 | 0.0473 | 7000.8237 | 3.871 PPM |
| 2002 | 2013 | 0.0267 | 0.0130 | 94.73 | 0.0499 | 7404.1516 | 3.612 PPM |
| 2014 | 2013 | 0.0359 | 0.0216 | 91.44 | 0.0607 | 13490.3592 | 2.665 PPM |

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 16

ELLIPSE: 3-D STATION CONFIDENCE REGIONS ( 95.000 %):

| IDENT. | MAJOR SEMI-AXIS | MEDIUM SEMI-AXIS | MINOR SEMI-AXIS |
|---|---|---|---|
| 2001 | 0.0161 | 0.0082 | 0.0059 |
| | A=180.0 V= 80.4 | A=298.9 V= 4.7 | A= 29.6 V= 8.3 |
| 2002 | 0.0152 | 0.0082 | 0.0054 |
| | A=161.8 V= 79.9 | A=307.9 V= 8.4 | A= 38.7 V= 5.6 |
| 2014 | 0.0690 | 0.0316 | 0.0237 |
| | A=345.0 V= 86.1 | A= 85.7 V= 0.7 | A=175.8 V= 3.8 |
| 2013 | 0.0754 | 0.0219 | 0.0157 |
| | A= 94.5 V= 72.1 | A=279.0 V= 17.9 | A=188.6 V= 1.3 |

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 17

ELLIPSE: 3-D RELATIVE STATION CONFIDENCE REGIONS ( 95.000 %):

| FROM | TO | MAJOR-SEMI | MED.-SEMI | MINOR-SEMI | SPATIAL DIST. | PRECISION |
|---|---|---|---|---|---|---|
| 2001 | 2002 | 0.0117 | 0.0051 | 0.0044 | 1165.1856 | 10.011 PPM |
| | | A= 0 V=90 | A= 90 V= 0 | A= 0 V= 0 | | |
| 2001 | 2014 | 0.0679 | 0.0311 | 0.0228 | 8095.2706 | 8.392 PPM |
| | | A=347 V=86 | A= 84 V= 1 | A=174 V= 4 | | |
| 2001 | 2013 | 0.0739 | 0.0201 | 0.0142 | 6317.2966 | 11.704 PPM |
| | | A= 93 V=72 | A=279 V=18 | A=188 V= 2 | | |
| 2002 | 2014 | 0.0677 | 0.0309 | 0.0226 | 7000.8237 | 9.666 PPM |
| | | A=342 V=85 | A= 83 V= 1 | A=173 V= 4 | | |
| 2002 | 2013 | 0.0745 | 0.0210 | 0.0148 | 7404.1516 | 10.064 PPM |
| | | A= 93 V=72 | A=278 V=18 | A=188 V= 1 | | |
| 2014 | 2013 | 0.0887 | 0.0363 | 0.0245 | 13490.3592 | 6.577 PPM |
| | | A= 85 V=76 | A=275 V=14 | A=185 V= 2 | | |

ELLIPSE successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 18

Figure D-11. (Sheet 7 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM CONSTRAINED ADJUSTMENT NAD-83

A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

PREPARE: ASCII input file: <coyote_1.iob>.
PREPARE successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 0

GETUP:

| PARAMETERS | | OBSERVATIONS | |
|---|---|---|---|
| Description | Number | Description | Number |
| All Stations | 5 | Directions | 0 |
| Fixed Stations | 3 | Distances | 0 |
| Free 3-D Stations | 2 | Azimuths | 0 |
| Free 2-D Stations | 0 | Vertical Angles | 0 |
| Free 1-D Stations | 0 | Zenithal Angles | 0 |
| Coord. Parameters | 6 | Angles | 0 |
| Astro. Latitudes | 0 | Heights | 0 |
| Astro. Longitudes | 0 | Height Differences | 0 |
| Geoid Records | 0 | Auxiliary Params. | 0 |
| All Aux. Pars. | 4 | 2-D Coords. | 0 |
| Direction Pars. | 0 | 2-D Coord. Diffs. | 0 |
| Scale Parameters | 1 | 3-D Coords. | 0 |
| Constant Pars. | 0 | 3-D Coord. Diffs. | 21 |
| Rotation Pars. | 3 | | |
| Translation Pars. | 0 | | |
| Total Parameters | 10 | Total Observations | 21 |

Degrees of Freedom = 11

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 1

GETUP: SUMMARY OF SELECTED OPTIONS

| OPTION | SELECTION |
|---|---|
| Computation Mode | Adjustment |
| Linear Unit | Metre |
| Maximum Iterations | 2 |
| Confidence Regions Selected | All |
| Confidence Region Dimensions | 1-D, 2-D, and 3-D |
| Print Input Station Data | On |
| Variance Factor Knowledge | Known |
| Confidence Level for Statistics | 95.000 |
| Dual-Height Mode | Off |
| Print Solution Vector | On All Iterations |
| Printed Ellipsoidal Coordinates | 5 Decimal Places |
| Print Adjusted X, Y, Z | On |
| Print Histograms | On |
| Print Misclosures | On All Iterations |
| Print Residuals | All |
| Variance Factor Usage | Scale Confidence Regions |
| Residual Rejection Criterion | Tau Max |
| Angular Misclosure Limit Factor | 10 |
| Linear Misclosure Limit Factor | 10 |
| Convergence Criterion | 0.001000 |

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 2

Figure D-12. GEOLAB adjustment output (constrained) (Sheet 1 of 7)

```
                    U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                              COYOTE DAM ADJUSTMENT  NAD-83
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000

CODE IDENT.    DESCRIPTOR      INITIAL VALUES
---- ------    ----------      --------------
 14  2006
                ELLIPSOIDAL :   39 11 34.37462 -123 10 10.28988        336.0850
                ASTRONOMIC  :   39 11 34.37462 -123 10 10.28988        336.0850
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2708280.4788    -4143494.7721    4009147.8933

 14  2013
                ELLIPSOIDAL :   39 15 12.11624 -123 13 17.48887        222.8350
                ASTRONOMIC  :   39 15 12.11624 -123 13 17.48887        222.8350
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2709665.3418    -4137409.4525    4014278.4657

 14  2014
                ELLIPSOIDAL :   39  7 57.41258 -123 12 14.77684        190.1700
                ASTRONOMIC  :   39  7 57.41258 -123 12 14.77684        190.1700
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2713032.7742    -4145300.4693    4003867.7960

 24  2001
                ELLIPSOIDAL :   39 12 14.43422 -123 11  6.45941        243.8658
                ASTRONOMIC  :   39 12 14.43422 -123 11  6.45941        243.8658
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2708942.2350    -4142043.8310    4010047.0300

 24  2002
                ELLIPSOIDAL :   39 11 37.00656 -123 11  0.94286        243.8815
                ASTRONOMIC  :   39 11 37.00656 -123 11  0.94286        243.8815
                GEOIDAL     :    0  0  0.00000    0  0  0.00000          0.0000
                CARTESIAN   :    -2709230.7400    -4142726.8330    4009152.5340

 94  WGSXX
                3DD  SCAL   :          0.00000
                3DD  ROTX   :          0.00000
                3DD  ROTY   :          0.00000
                3DD  ROTZ   :          0.00000
GETUP successfully completed.
------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      3
FORMEQ:                NOTE 6: Reordering was done.
AT       TO       OBS TYPE              OBSERVATION  APPROX.SIG.   MISCLOSURE
-------- -------- --------------- --------------- ------------ ------------
2001     2006     3-D X-Coord Diff         666.6170       0.0037       -4.8608
2001     2006     3-D Y-Coord Diff       -1441.5480       0.0045       -9.3931
2001     2006     3-D Z-Coord Diff        -908.2800       0.0028        9.1433
2002     2006     3-D X-Coord Diff         953.2950       0.0022       -3.0338
2002     2006     3-D Y-Coord Diff        -748.3180       0.0044      -19.6211
2002     2006     3-D Z-Coord Diff         -16.7100       0.0029       12.0693
2001     2002     3-D X-Coord Diff        -286.6690       0.0024       -1.8360
2001     2002     3-D Y-Coord Diff        -693.2190       0.0026       10.2170
2001     2002     3-D Z-Coord Diff        -891.5890       0.0025       -2.9070
2001     2002     3-D X-Coord Diff        -286.6790       0.0026       -1.8260
2001     2002     3-D Y-Coord Diff        -693.2230       0.0030       10.2210
2001     2002     3-D Z-Coord Diff        -891.5780       0.0026       -2.9180
2014     2002     3-D X-Coord Diff        3799.0050       0.0129        3.0292
2014     2002     3-D Y-Coord Diff        2554.0180       0.0101       19.6183
2014     2002     3-D Z-Coord Diff        5296.7980       0.0113      -12.0600
2013     2001     3-D X-Coord Diff         718.2440       0.0059        4.8628
2013     2001     3-D Y-Coord Diff       -4643.7750       0.0083        9.3965
2013     2001     3-D Z-Coord Diff       -4222.2870       0.0059       -9.1487
FORMEQ successfully completed.
------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      4
```

Figure D-12. (Sheet 2 of 7)

```
                    U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          COYOTE DAM ADJUSTMENT  NAD-83
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000

SOLVE:      Solution (Iteration Count = 1):
CODE IDENT.   TYPE                  INITIAL            DX              UPDATED
---- -------- --------- ------------------- ------------- ------------------
 24  2001     LATITUDE     39  12  14.43422       0.01413    39  12  14.44836
 24  2001     LONGITUDE  -123  11   6.45941       0.04476  -123  11   6.41465
 24  2001     HEIGHT              243.86577      13.93968          257.80545

 24  2002     LATITUDE     39  11  37.00656      -0.06729    39  11  36.93927
 24  2002     LONGITUDE  -123  11   0.94286       0.34171  -123  11   0.60115
 24  2002     HEIGHT              243.88154      21.63406          265.51561

 94  WGSXX    3DD SCAL              0.00000      -0.00161           -0.00161
 94  WGSXX    3DD ROTX              0.00000       0.03270            0.03270
 94  WGSXX    3DD ROTY              0.00000      -0.06406           -0.06406
 94  WGSXX    3DD ROTZ              0.00000      -0.04338           -0.04338
SOLVE successfully completed.
-------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      5
-------------------------------------------------------------------------------
FORMEQ:                  FORMEQ successfully completed.
-------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      6
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
SOLVE:          Adjusted Values (Iteration Count = 2):
CODE IDENT.   TYPE                  INITIAL            DX              ADJUSTED
---- -------- --------- ------------------- ------------- ------------------
 14  2006     LATITUDE     39  11  34.37462         FIXED
 14  2006     LONGITUDE  -123  10  10.28988         FIXED
 14  2006     HEIGHT              336.08500         FIXED

 14  2013     LATITUDE     39  15  12.11624         FIXED
 14  2013     LONGITUDE  -123  13  17.48887         FIXED
 14  2013     HEIGHT              222.83500         FIXED

 14  2014     LATITUDE     39   7  57.41258         FIXED
 14  2014     LONGITUDE  -123  12  14.77684         FIXED
 14  2014     HEIGHT              190.17000         FIXED

 24  2001     LATITUDE     39  12  14.44836       0.00000    39  12  14.44836
 24  2001     LONGITUDE  -123  11   6.41465       0.00000  -123  11   6.41465
 24  2001     HEIGHT              257.80545      -0.00000          257.80545

 24  2002     LATITUDE     39  11  36.93927       0.00000    39  11  36.93927
 24  2002     LONGITUDE  -123  11   0.60115      -0.00000  -123  11   0.60115
 24  2002     HEIGHT              265.51561       0.00000          265.51561

 94  WGSXX    3DD SCAL             -0.00161       0.00000           -0.00161
 94  WGSXX    3DD ROTX              0.03270      -0.00000            0.03270
 94  WGSXX    3DD ROTY             -0.06406       0.00000           -0.06406
 94  WGSXX    3DD ROTZ             -0.04338       0.00000           -0.04338

-------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      7
```

Figure D-12. (Sheet 3 of 7)

```
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                      COYOTE DAM ADJUSTMENT  NAD-83
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000
--------------------------------------------------------------------------------
                          Adjusted Cartesian Coordinates:

CODE IDENT.         X-COORDINATE       Y-COORDINATE       Z-COORDINATE
---- -------- ------------------ ------------------ ------------------
 24  2001          -2708947.0978      -4142053.2284       4010056.1788
 24  2002          -2709233.7715      -4142746.4512       4009164.5972
SOLVE successfully completed.
--------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      8
--------------------------------------------------------------------------------
INVERT:          INVERT successfully completed.
--------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page      9
--------------------------------------------------------------------------------
RESID:

STATION    3-D COORD DIFFS    STD.DEV.    RESIDUAL    STD.DEV.   STAN.RES.
--------   --------------   ----------  ----------  ----------  ----------
2001          -2708942.2350
              -4142043.8310
               4010047.0300
2006          -2708275.6180      0.0050      0.0020      0.0041      0.4865
              -4143485.3790      0.0060      0.0043      0.0045      0.9530
               4009138.7500      0.0040     -0.0055      0.0026     -2.1060
============================== End of Observation Set ==============================
2002          -2709230.7400
              -4142726.8330
               4009152.5340
2006          -2708277.4450      0.0030     -0.0024      0.0016     -1.5309
              -4143475.1510      0.0050     -0.0031      0.0032     -0.9650
               4009135.8240      0.0040      0.0063      0.0026      2.3907
============================== End of Observation Set ==============================
2001          -2708941.0950
              -4142050.6320
               4010040.8370
2002          -2709227.7640      0.0030     -0.0046      0.0020     -2.2625
              -4142743.8510      0.0040     -0.0036      0.0031     -1.1706
               4009149.2480      0.0040      0.0072      0.0032      2.2786
============================== End of Observation Set ==============================
2001          -2708946.1080
              -4142048.2180
               4010039.9500
2002          -2709232.7870      0.0040      0.0054      0.0033      1.6090
              -4142741.4410      0.0040      0.0004      0.0031      0.1285
               4009148.3720      0.0040     -0.0038      0.0032     -1.1993
============================== End of Observation Set ==============================
2014          -2713050.5170
              -4145286.8310
               4003867.5850
2002          -2709251.5120      0.0180     -0.0035      0.0149     -0.2328
              -4142732.8130      0.0160     -0.0015      0.0090     -0.1659
               4009164.3830      0.0200      0.0047      0.0141      0.3373
============================== End of Observation Set ==============================
2013          -2709663.6000
              -4137421.4500
               4014263.6620
2014          -2713031.0290      0.0150     -0.0018      0.0105     -0.1739
              -4145312.4700      0.0460      0.0055      0.0419      0.1303
               4003852.9890      0.0330      0.0010      0.0293      0.0344

--------------------------------------------------------------------------------
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     10
```

Figure D-12. (Sheet 4 of 7)

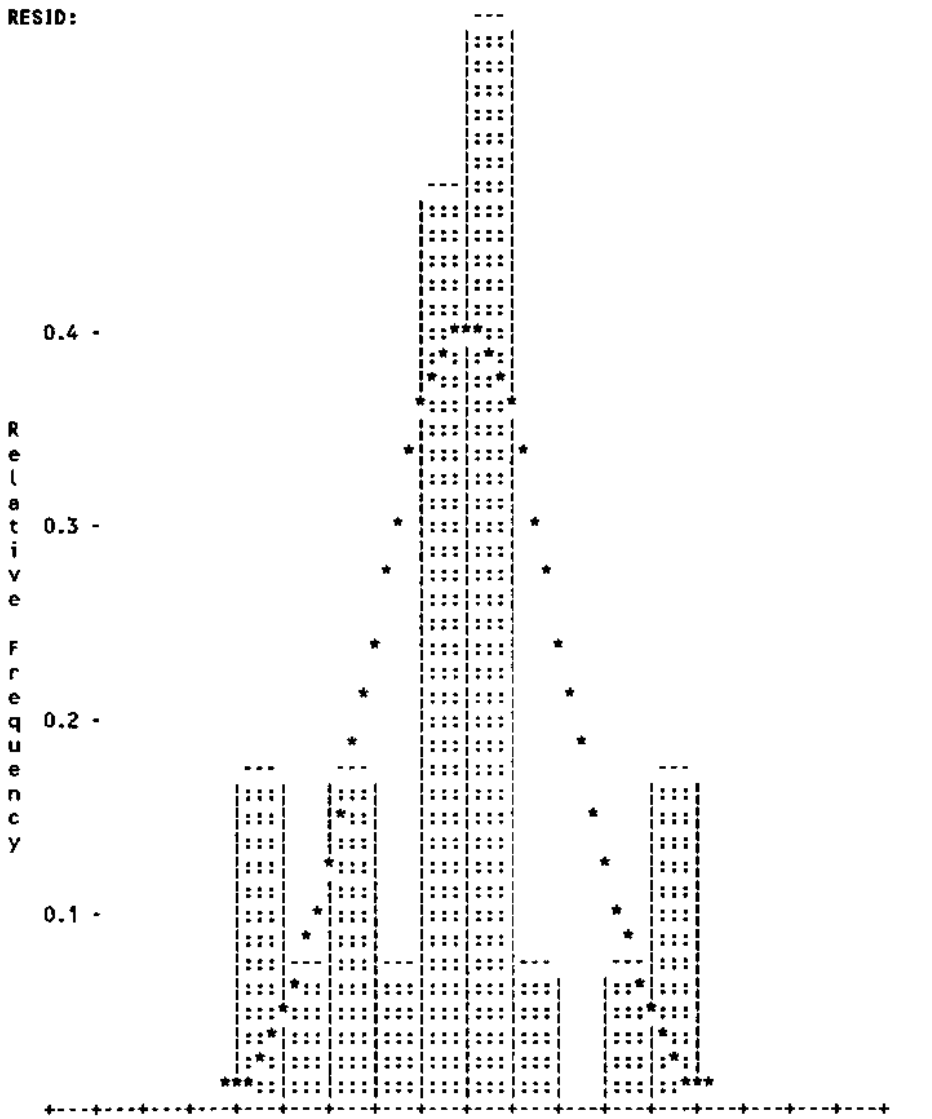
U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD-83

A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

| STATION | 3-D COORD DIFFS | STD.DEV. | RESIDUAL | STD.DEV. | STAN.RES. |
|---|---|---|---|---|---|
| ========== End of Observation Set ========== | | | | | |
| 2013 | -2709663.6000 | | | | |
| | -4137421.4500 | | | | |
| | 4014263.6620 | | | | |
| 2001 | -2708945.3560 | 0.0070 | 0.0003 | 0.0026 | 0.1237 |
| | -4142065.2250 | 0.0200 | -0.0004 | 0.0137 | -0.0312 |
| | 4010041.3750 | 0.0150 | -0.0005 | 0.0083 | -0.0555 |
| ========== End of Observation Set ========== | | | | | |

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 11

RESID:




GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 12

Figure D-12. (Sheet 5 of 7)

```
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                      COYOTE DAM ADJUSTMENT  NAD-83
A=  6378137.000 B=  6356752.314 X0=       0.000 Y0=       0.000 Z0=       0.000

RESID:

                    S T A T I S T I C S    S U M M A R Y

     Residual Critical Value Type          Tau Max
     Residual Critical Value                2.7083
     Convergence Criterion                  0.001000
     Final Iteration Counter Value          2
     Confidence Level Used                  95.0000
     Number of Flagged Residuals            0
     Estimated Variance Factor              1.0944
     Number of Degrees of Freedom           11

                  Chi-Square Test on the Variance Factor:

                  5.4919e-001  <  1.0000  <  3.1549e+000  ?

                            THE TEST PASSES.

RESID successfully completed.
GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     13


ELLIPSE:

 NOTE:  All confidence regions were computed using the following factors:

        Variance factor used      =         1.09438

        Estimated variance factor =         1.09438

        1-D expansion factor      =           1.960

        2-D expansion factor      =           2.448

        3-D expansion factor      =           2.795


        Note that, for relative confidence regions, precisions are
        computed from the ratio of the major semi-axis and the spatial
        distance between the two stations.

        Error ellipses for which all covariance matrix elements
        were not computed by INVERT, are marked with an asterisk (*).

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     14
```

**Figure D-12. (Sheet 6 of 7)**

```
                    U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          COYOTE DAM ADJUSTMENT  NAD-83
A=  6378137.000 B=  6356752.314 XO=        0.000 YO=        0.000 ZO=        0.000

ELLIPSE:                  AUXILIARY PARAMETER CONFIDENCE INTERVALS ( 95.000 %):

IDENT.    TYPE      CLASS          ADJ VALUE     1.96 SIGMA
--------  --------- -------- ---------------- -------------
WGSXX     3DD       SCAL             -0.0016        1.1261
                    ROTX        0  0   0.03   0  0   0.82
                    ROTY        0  0  -0.06   0  0   1.27
                    ROTZ        0  0  -0.04   0  0   1.37

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     15



ELLIPSE:          2-D AND 1-D STATION CONFIDENCE REGIONS ( 95.000 %):

IDENT.     MAJOR SEMI-AXIS  MINOR SEMI-AXIS  AZ(MAJ)        VERTICAL
--------  ----------------- ---------------- --------  ---------------
2001                0.0066           0.0048    107.22           0.0133
2002                0.0062           0.0044    125.62           0.0127

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     16



ELLIPSE:          2-D AND 1-D RELATIVE STATION CONFIDENCE REGIONS ( 95.000 %):

FROM      TO        MAJ.SEMI MIN.SEMI AZ(MAJ) VERTICAL SPATIAL DIST.     PRECISION
--------  --------  -------- -------- ------- -------- -------------  ------------
2001      2002         0.0045   0.0036  108.07   0.0082     1165.1856     3.846 PPM

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     17



ELLIPSE:          3-D STATION CONFIDENCE REGIONS ( 95.000 %):

IDENT.           MAJOR SEMI-AXIS       MEDIUM SEMI-AXIS        MINOR SEMI-AXIS
--------  ---------------------- ---------------------- ----------------------
2001                       0.0191                 0.0070                 0.0056
                  A=106.6 V= 81.9        A=270.0 V=  7.8        A=  0.3 V=  2.3
2002                       0.0182                 0.0070                 0.0051
                  A= 90.0 V= 87.6        A=306.2 V=  1.9        A=216.2 V=  1.4

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     18



ELLIPSE:          3-D RELATIVE STATION CONFIDENCE REGIONS ( 95.000 %):

FROM      TO        MAJOR-SEMI  MED.-SEMI MINOR-SEMI  SPATIAL DIST.     PRECISION
--------  --------  ---------- ---------- ----------  -------------  ------------
2001      2002          0.0117     0.0050     0.0042     1165.1856    10.027 PPM
                  A=  0 V=90 A= 90 V= 0 A=  0 V= 0
ELLIPSE successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]      Page     19
```

Figure D-12. (Sheet 7 of 7)

(1:10,000). The relative line accuracy between 2001 and 2002 on the constrained adjustment was 3.846 ppm, or 1:260,000. This indicates excellent connections with existing control.

*d.* The variance factor shown on page 14 of each adjustment is within acceptable limits (0.5 to 1.5). As such, it could be used to determine outlier limits for rejection of data, as explained in Chapter 11.

*e.* The residual corrections to each baseline component are shown on page 10 of each adjustment. Special review is made of the standardized residuals, which one will find is approximately comparable to normalized residuals in GEOLAB software. None of the residuals were flagged (based on Tau Max testing) for exceeding tolerance.

*f.* The 3D positional and relative confidence regions (ellipsoid) and 3D line accuracy precessions are shown at the end of each adjustment. These statistics are not applicable for most USACE work.

*g.* Of all the output statistics, only the residuals, standardized residuals, relative 2D/1D line precessions, and variance factor have useful application for USACE work. The histograms, Chi-square tests, 3D ellipsoid, etc. are useful only if one understands their derivation and application.

*h.* The results of the free and constrained adjustments in this example were not significantly different. This is usually not the case -- typically, station/line accuracies degrade on the constrained adjustment.

*Section II*
*Survey No. 2: Precise Control Survey*
*(Dworshak Dam, Idaho)*

## D-7. General

A high precision GPS control survey may be performed at sites for structural deformation monitoring. Accurate control in the vicinity of the structure is critical. Absolute NGRS coordinate on monitoring points is of lesser importance. NGRS control may be brought into one of the reference points with GPS. Only the NGRS coordinates of this fixed point are held fixed for all subsequent adjustments in the vicinity of the structure.

## D-8. Project Description

Survey example No. 2 was conducted in the vicinity of Dworshak Dam, Idaho. A diagram of the project is shown in Figure D-13. Baseline data from the NGRS control to one point (Fish Hatchery - 4001) at the project site were collected and other baseline data for baselines between 4001, Big Eddy (4002), and four points on the Dworshak Dam and Reservoir (4003, 4004, 4005, and 4006) as shown in Figure D-14. Loop closure checks were done for the complete network by using the loop closure routine shown in Figure D-15. The resultant precision for the loop is 0.43 ppm (1:2,300,000).

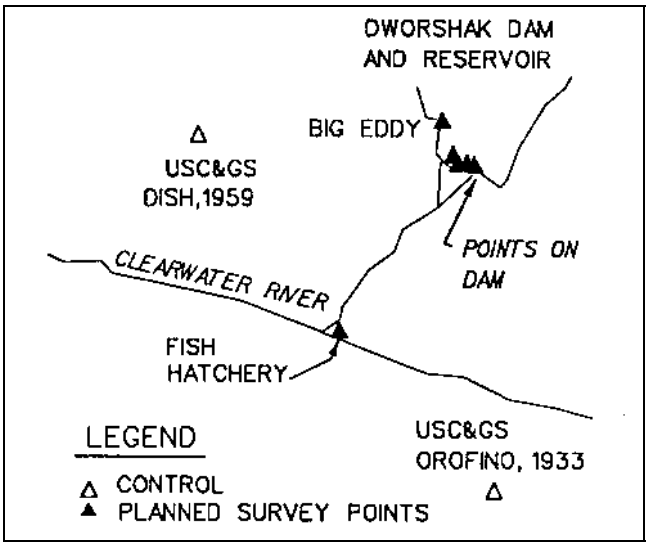



**Figure D-13. Dworshak Dam and Project area**

## D-9. Adjustment

*a.* An IOB file for the adjustment based on the formulated baselines was set up. Station USC&GS Dish, 1959, and USC&GS Orofino, 1933, were held fixed to establish NGRS control on Corps of Engineers Station 4001 at the project site. Then, for the next adjustment, 4001 was held fixed to adjust station 4002, 4003, 4004, 4005, and 4006. This free adjustment is shown in Figure D-16. Analysis of the adjustment was done as in Survey No. 1 and detailed in Chapter 11.

*b.* The resultant adjustment statistics are shown on page 14 of Figure D-16. The 2D station confidence is on the order of 0.04 m (2DRMS) and $\pm$0.06 m in the vertical. The largest line accuracy is 36.322 ppm (1:27,000)

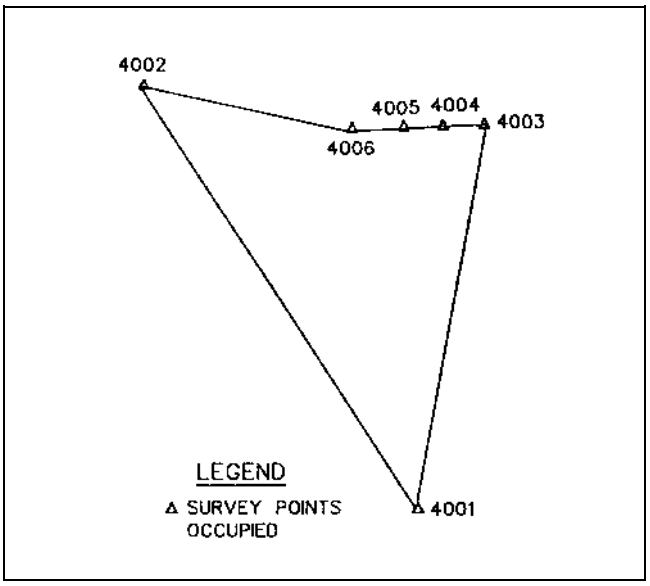



**Figure D-14. GPS project diagram (Dworshak)**

over a short (62 m) baseline. This would be acceptable even though a 1:100,00 relative accuracy is required. Due to fixed centering errors, maintaining 1:100,000 relative accuracies over lines less than 200 to 500 m is unrealistic.

*Section III*
*Survey No. 3: Upper Saginaw River Control Project. (Saginaw, Michigan).*

## D-10. Planning Phase

*a.* The GPS survey was planned for 24-25 March 1993, Julian day 083 and 084 in the vicinity of Saginaw, Michigan.

*b.* This project was to establish Second-Order control, using GPS, at the Upper Saginaw River. The project area covered from Green Point down to the railroad bridge of the upper end of the condition survey project area, see Figure D-17. These control stations were to

```
Trimble Loop Closure Utility

Start Traverse at Station:  4006
Starting Coords :  46x30'56.88832"ØN   116x17'48.33684"ØW          489.843

Baseline 1
File Name: 06053001.FIX
From Station:  4006                    To Station:  4005
Distance Travelled (m):          82.829
Current Coords  :  46x30'55.20552"ØN   116x17'46.75486"ØW          500.412

Baseline 2
File Name: 05042993.FIX
From Station:  4005                    To Station:  4004
Distance Travelled (m):         124.262
Current Coords  :  46x30'54.30015"ØN   116x17'44.23756"ØW          489.809

Baseline 3
File Name: 04032981.FIX
From Station:  4004                    To Station:  4003
Distance Travelled (m):         214.384
Current Coords  :  46x30'51.68841"ØN   116x17'42.38493"ØW          497.376

Baseline 4
File Name: 01032992.FIX
From Station:  4003                    To Station:  4001
Distance Travelled (m):        2872.755
Current Coords  :  46x30'05.98881"ØN   116x18'27.67811"ØW          308.887

Baseline 5
File Name: 01023012.FIX
From Station:  4001                    To Station:  4002
Distance Travelled (m):        6122.940
Current Coords  :  46x31'41.46032"ØN   116x18'24.06337"ØW          490.036

Baseline 6
File Name: 02063001.FIX
From Station:  4002                    To Station:  4006
Distance Travelled (m):        7695.981
Current Coords  :  46x30'56.88826"ØN   116x17'48.33690"ØW          489.941

End Traverse at Station:  4006
Distance Travelled (m):        7695.981    Precision (ppm):        0.43
dx:     -0.001      dy:      0.001      dz:     -0.003      dh:     -0.002
Ending Coords   :  46x30'56.88826"ØN   116x17'48.33690"ØW          489.941
Reference Coords:  46x30'56.88832"ØN   116x17'48.33684"ØW          489.943
```

**Figure D-15. Loop closure (Dworshak)**

```
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                                DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
PREPARE:

ASCII input file: <wal_1.iob>.

PREPARE successfully completed.

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  0
```



```
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                                DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
GETUP:
```

| PARAMETERS | | OBSERVATIONS | |
|---|---|---|---|
| Description | Number | Description | Number |
| All Stations | 6 | Directions | 0 |
| Fixed Stations | 1 | Distances | 0 |
| Free 3-D Stations | 5 | Azimuths | 0 |
| Free 2-D Stations | 0 | Vertical Angles | 0 |
| Free 1-D Stations | 0 | Zenithal Angles | 0 |
| Coord. Parameters | 15 | Angles | 0 |
| Astro. Latitudes | 0 | Heights | 0 |
| Astro. Longitudes | 0 | Height Difference | 0 |
| Geoid Records | 0 | Auxiliary Params. | 0 |
| All Aux. Pars. | 0 | 2-D Coords. | 0 |
| Direction Pars. | 0 | 2-D Coord. Diffs. | 0 |
| Scale Parameters | 0 | 3-D Coords. | 0 |
| Constant Pars. | 0 | 3-D Coord. Diffs. | 60 |
| Rotation Pars. | 0 | | |
| Translation Pars. | 0 | | |
| Total Parameters | 15 | Total Observations | 60 |
| Degrees of Freedom = | 45 | | |

```
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  1
```

**Figure D-16. GEOLAB adjustment output (Sheet 1 of 8)**

```
------------------------------------------------------------------------
          U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                        DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
------------------------------------------------------------------------
GETUP


------------------------------------------------------------------------
                  SUMMARY  OF  SELECTED  OPTIONS
------------------------------------------------------------------------
 OPTION                                |     SELECTION
---------------------------------------|--------------------------------
 Computation Mode                      |     Adjustment
 Linear Unit                           |     Metre
 Maximum Iterations                    |     2
 Confidence Regions Selected           |     All
 Confidence Region Dimensions          |     1-D and 2-D only
 Print Input Station Data              |     Off
 Variance Factor Knowledge             |     Known
 Confidence Level for Statistics       |     95.000
 Dual-Height Mode                      |     Off
 Print Solution Mode                   |     Only Adjusted Values
 Printed Ellipsoidal Coordinates       |     5 Decimal Places
 Print Adjusted X, Y, Z                |     On
 Print Histograms                      |     On
 Print Misclosures                     |     On
 Print Residuals                       |     On All Iterations
 Variance Factor Usage                 |     Scale Confidence Regions
 Residual Rejection Criterion          |     Tau Max
 Angular Misclosure Limit Factor       |     10
 Linear Misclosure Limit Factor        |     10
 Convergence Criterion                 |     0.001000
---------------------------------------|--------------------------------

SETUP successfully completed.




------------------------------------------------------------------------
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  2
```

Figure D-16. (Sheet 2 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

FORMEQ:

NOTE 6: Reordering was done.

| AT | TO | OBS TYPE | OBSERVATION | APPROX.SIG. | MISCLOSURE |
|---|---|---|---|---|---|
| 4001 | 4003 | 3-D X-Coord Diff | 2408.6880 | 0.0029 | 22.8708 |
| 4001 | 4003 | 3-D Y-Coord Diff | -193.5840 | 0.0016 | 25.8258 |
| 4001 | 4003 | 3-D Z-Coord Diff | 1108.0180 | 0.0021 | -26.6407 |
| 4004 | 4003 | 3-D X-Coord Diff | 7.1790 | 0.0007 | 22.7040 |
| 4004 | 4003 | 3-D Y-Coord Diff | -74.6270 | 0.0003 | 21.7690 |
| 4004 | 4003 | 3-D Z-Coord Diff | -50.0120 | 0.0006 | -25.7900 |
| 4001 | 4004 | 3-D X-Coord Diff | 2401.5070 | 0.0055 | .1688 |
| 4001 | 4004 | 3-D Y-Coord Diff | -118.9530 | 0.0065 | 4.0528 |
| 4001 | 4004 | 3-D Z-Coord Diff | 1158.0230 | 0.0062 | -0.8437 |
| 4001 | 4002 | 3-D X-Coord Diff | 2108.6340 | 0.0061 | -1.6862 |
| 4001 | 4002 | 3-D Y-Coord Diff | 1204.4260 | 0.0079 | 36.7548 |
| 4001 | 4002 | 3-D Z-Coord Diff | 2160.2690 | 0.0067 | -27.6797 |
| 4001 | 4003 | 3-D X-Coord Diff | 2408.6870 | 0.0055 | 22.8718 |
| 4001 | 4003 | 3-D Y-Coord Diff | -193.5780 | 0.0072 | 25.8198 |
| 4001 | 4003 | 3-D Z-Coord Diff | 1108.0110 | 0.0062 | -26.6337 |
| 4001 | 4005 | 3-D X-Coord Diff | 2359.1380 | 0.0047 | -0.9472 |
| 4001 | 4005 | 3-D Y-Coord Diff | -83.5390 | 0.0122 | 5.9208 |
| 4001 | 4005 | 3-D Z-Coord Diff | 1184.9630 | 0.0073 | -7.2267 |
| 4005 | 4004 | 3-D X-Coord Diff | 42.3580 | 0.0008 | 1.1270 |
| 4005 | 4004 | 3-D Y-Coord Diff | -35.4190 | 0.0015 | -1.8630 |
| 4005 | 4004 | 3-D Z-Coord Diff | -26.9330 | 0.0006 | 6.3760 |
| 4001 | 4002 | 3-D X-Coord Diff | 2108.6240 | 0.0045 | -1.6762 |
| 4001 | 4002 | 3-D Y-Coord Diff | 1204.4190 | 0.0104 | 36.7618 |
| 4001 | 4002 | 3-D Z-Coord Diff | 2160.2710 | 0.0063 | -27.6817 |
| 4001 | 4006 | 3-D X-Coord Diff | 2348.8140 | 0.0033 | 32.4128 |
| 4001 | 4006 | 3-D Y-Coord Diff | -28.3330 | 0.0019 | 24.3928 |
| 4001 | 4006 | 3-D Z-Coord Diff | 1213.1260 | 0.0021 | -23.8437 |
| 4006 | 4005 | 3-D X-Coord Diff | 10.3400 | 0.0008 | -33.3760 |
| 4006 | 4005 | 3-D Y-Coord Diff | -55.2020 | 0.0004 | -18.4760 |
| 4006 | 4005 | 3-D Z-Coord Diff | -28.1650 | 0.0007 | 16.6190 |
| 4002 | 4006 | 3-D X-Coord Diff | 240.1770 | 0.0031 | 34.1020 |
| 4002 | 4006 | 3-D Y-Coord Diff | -1232.7570 | 0.0020 | -12.3640 |
| 4002 | 4006 | 3-D Z-Coord Diff | -947.1440 | 0.0019 | 3.8370 |
| 4002 | 4005 | 3-D X-Coord Diff | 250.5120 | 0.0027 | 0.7310 |
| 4002 | 4005 | 3-D Y-Coord Diff | -1287.9560 | 0.0040 | -30.8430 |
| 4002 | 4005 | 3-D Z-Coord Diff | -975.3050 | 0.0031 | 20.4520 |
| 4001 | 4005 | 3-D X-Coord Diff | 2359.1440 | 0.0055 | -0.9532 |
| 4001 | 4005 | 3-D Y-Coord Diff | -83.5400 | 0.0067 | 5.9218 |
| 4001 | 4005 | 3-D Z-Coord Diff | 1184.9690 | 0.0063 | -7.2327 |
| 4001 | 4006 | 3-D X-Coord Diff | 2348.8070 | 0.0054 | 32.4198 |
| 4001 | 4006 | 3-D Y-Coord Diff | -28.3370 | 0.0066 | 24.3968 |
| 4001 | 4006 | 3-D Z-Coord Diff | 1213.1310 | 0.0062 | -23.8487 |
| 4002 | 4003 | 3-D X-Coord Diff | 300.0520 | 0.0022 | 24.5590 |
| 4002 | 4003 | 3-D Y-Coord Diff | -1398.0030 | 0.0043 | -10.9360 |



Figure D-16. (Sheet 3 of 8)

```
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                                DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
FORMEQ:

AT    TO    OBS TYPE          OBSERVATION  APPROX.SIG.  MISCLOSURE
----- ----- ----------------- ------------ ------------ ----------
4002  4003  3-D X-Coord Diff  -1052.2550       0.0024      1.0430
4006  4003  3-D X-Coord Diff     59.8780       0.0007     -9.5460
4006  4003  3-D Y-Coord Diff   -165.2500       0.0015      1.4320
4006  4003  3-D Z-Coord Diff   -165.2500       0.0006     -2.7900
4001  4002  3-D X-Coord Diff   2108.6250       0.0045     -1.6772
4001  4002  3-D Y-Coord Diff   1204.4170       0.0104     36.7638
4001  4002  3-D Z-Coord Diff   2160.2740       0.0063    -27.6847
4001  4002  3-D X-Coord Diff   2108.6270       0.0043     -1.6792
4001  4002  3-D Y-Coord Diff   1204.4160       0.0028     36.7648
4001  4002  3-D Z-Coord Diff   2160.2680       0.0029    -27.6787
4001  4002  3-D X-Coord Diff   2108.6320       0.0063     -1.6842
4001  4002  3-D Y-Coord Diff   1204.4280       0.0078     36.7528
4001  4002  3-D Z-Coord Diff   2160.2620       0.0062    -27.6727
4001  4002  3-D X-Coord Diff   2108.6250       0.0045     -1.6772
4001  4002  3-D Y-Coord Diff   1204.4170       0.0101     36.7638
4001  4002  3-D Z-Coord Diff   2160.2780       0.0061    -26.6887

FORMEQ successfully completed.
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  4

                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                                DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
SOLVE:

SOLVE successfully completed.

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  5

                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                                DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
FORMEQ:

FORMEQ successfully completed.

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  6
```

Figure D-16. (Sheet 4 of 8)

```
            U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
-------------------------------------------------------------------
SOLVE:

Adjusted Values (Iteration Count = 2):

CODE IDENT. TYPE                 INITIAL       DX         ADJUSTED
---- ----- --------- ------------------- -------- ---------------
 14  4001  LATITUDE    46  30  5.78733    FIXED
 14  2006  LONGITUDE -116  19 17.36405    FIXED
 14  2006  HEIGHT             312.18200   FIXED

 24  4003  LATITUDE    46  30 51.48677  0.00000  46  30 51.48677
 24  4003  LONGITUDE -116  17 42.07099  0.00000 -116 17 42.07099
 24  4003  HEIGHT             500.68216  0.00001        500.68217

 24  4004  LATITUDE    46  30 54.09853  0.00000  46  30 54.09853
 24  4004  LONGITUDE -116  17 43.92366 -0.00000 -116 17 43.92366
 24  4004  HEIGHT             493.11850  0.00000        493.11851

 24  4002  LATITUDE    46  30 41.25876  0.00000  46 31  41.25876
 24  4002  LONGITUDE -116  18 23.74916 -0.00001 -116 18 23.74917
 24  4002  HEIGHT             493.34210  0.00003        493.34213

 24  4005  LATITUDE    46  30 55.00394 -0.00000  46 30  36.93927
 24  4005  LONGITUDE -116  17 46.44097 -0.00000 -116 17 46.44097
 24  4005  HEIGHT             503.72111  0.00000        503.72111

 24  4006  LATITUDE    46  30 56.68676  0.00000 46 30  56.68676
 24  4006  LONGITUDE -116  17 48.02294  0.00001 -116 17 48.02294
 24  4006  HEIGHT             493.25364  0.00003        493.25367
-------------------------------------------------------------------
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  7
-------------------------------------------------------------------
            U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
-------------------------------------------------------------------
Adjusted Cartesian Coordinates:

CODE IDENT.      X-COORDINATE      Y-COORDINATE      Z-COORDINATE
---- ------ ----------------- ----------------- -----------------
 24  4003       -1948002.5548     -3942346.3361      4605137.8787
 24  4004       -1948009.7358     -3942271.7102      4605187.8935
 24  4002       -1948302.6080     -3940948.3316      4606190.1331
 24  4005       -1948052.0934     -3942236.2903      4605213.8271
 24  4006       -1948062.4335     -3942181.0887      4605242.9935

SOLVE successfully completed.

-------------------------------------------------------------------
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  8
-------------------------------------------------------------------
            U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          DWORSHAK DAM
A=  6378137.000 B=  6356752.314 X0=  0.000 Y0=  0.000 Z0=  0.000
-------------------------------------------------------------------
INVERT:

INVERT successfully completed.

-------------------------------------------------------------------
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page  9
```

Figure D-16. (Sheet 5 of 8)

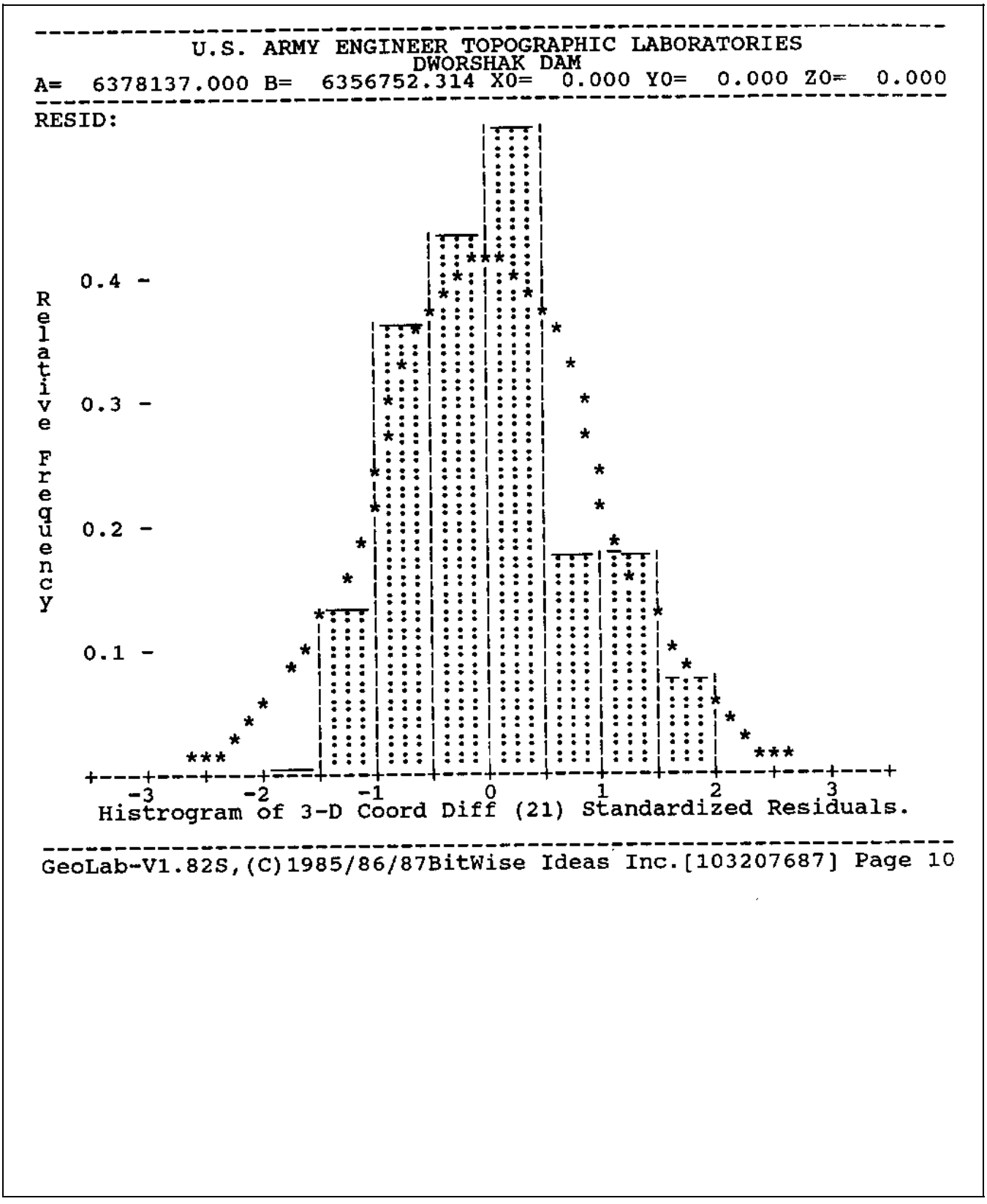



Figure D-16. (Sheet 6 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

RESID:

S T A T I S T I C S  S U M M A R Y

| | |
|---|---|
| Residual Critical Value Type | Tau Max |
| Residual Critical Value | 3.3469 |
| Convergence Criterion | 0.001000 |
| Final Iteration Counter Value | 2 |
| Confidence Level Used | 95.0000 |
| Number of Flagged Residuals | 0 |
| Estimated Variance Factor | 0.8676 |
| Number of Degrees of Freedom | 45 |

Chi-Square Test on the Variance Factor:

5.9685e-001 < 1.0000 < 1.3763e+000 ?

THE TEST PASSES.

RESID successfully completed.



U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

ELLIPSE:

NOTE: All confidence regions were computed using the following factors:

| | | |
|---|---|---|
| Variance factor used | = | 0.86755 |
| Estimated variance factor | = | 0.86755 |
| 1-D expansion factor | = | 1.960 |
| 2-D expansion factor | = | 2.448 |
| 3-D expansion factor | = | 2.795 |

Note that, for relative confidence regions, precisions are computed from the ration of the major semi-axis and the spatial distance between the two stations.

Error ellipses for which all covariance matrix elements were not computed by INVERT, are marked with an asterick(*)



Figure D-16. (Sheet 7 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

ELLIPSE:

2-D AND 1-D STATION CONFIDENCE REGIONS ( 95.000 %):

| IDENT. | MAJOR SEMI-AXIS | MINOR SEMI-AXIS | AZ(MAJ) | VERTICAL |
|---|---|---|---|---|
| 4003 | 0.0034 | 0.0022 | 76.62 | 0.0056 |
| 4004 | 0.0036 | 0.0023 | 82.71 | 0.0057 |
| 4002 | 0.0035 | 0.0026 | 89.02 | 0.0061 |
| 4005 | 0.0035 | 0.0023 | 82.89 | 0.0057 |
| 4006 | 0.0035 | 0.0022 | 79.03 | 0.0056 |

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page 13

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A= 6378137.000 B= 6356752.314 X0= 0.000 Y0= 0.000 Z0= 0.000

ELLIPSE:

2-D and 1-D RELATIVE STATION CONFIDENCE REGIONS ( 95.000 %):

| FROM | TO | MAJ.SEMI | MIN.SEMI | AZ(MAJ) | VERT. | SPAT.DIST. | PREC. |
|---|---|---|---|---|---|---|---|
| 4003 | 4004 | 0.0023 | 0.0008 | 89.79 | 0.0033 | 90.1225 | 25.220PPM |
| 4003 | 4002 | 0.0033 | 0.0026 | 96.46 | 0.0057 | 1775.2993 | 1.847PPM |
| 4003 | 4005 | 0.0025 | 0.0016 | 104.89 | 0.0038 | 143.1265 | 17.408PPM |
| 4003 | 4006 | 0.0018 | 0.0014 | 130.30 | 0.0027 | 204.7957 | 8.998PPM |
| 4004 | 4002 | 0.0035 | 0.0027 | 97.42 | 0.0059 | 1685.7014 | 2.064PPM |
| 4004 | 4005 | 0.0019 | 0.0014 | 128.56 | 0.0027 | 61.4342 | 30.745PPM |
| 4004 | 4006 | 0.0026 | 0.0016 | 102.27 | 0.0039 | 118.4286 | 21.633PPM |
| 4002 | 4005 | 0.0033 | 0.0025 | 92.33 | 0.0056 | 1634.8752 | 2.019PPM |
| 4002 | 4006 | 0.0033 | 0.0024 | 85.85 | 0.0056 | 1573.0376 | 2.098PPM |
| 4005 | 4006 | 0.0023 | 0.0009 | 88.94 | 0.0033 | 62.8290 | 36.322PPM |

ELLIPSE successfully completed.

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page 14

Figure D-16. (Sheet 8 of 8)

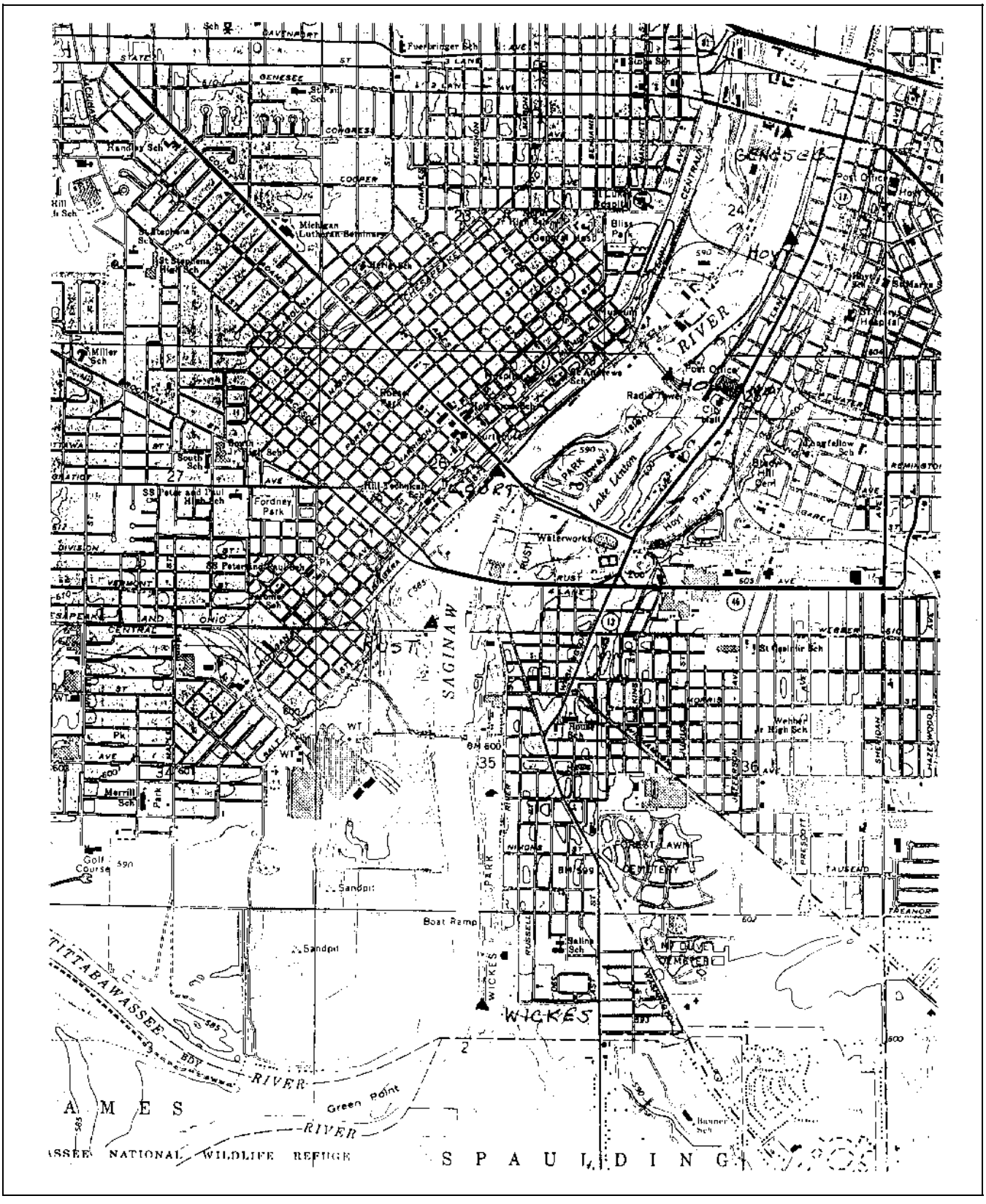



**Figure D-17. Project area and control points, Upper Saginaw River project (Continued)**

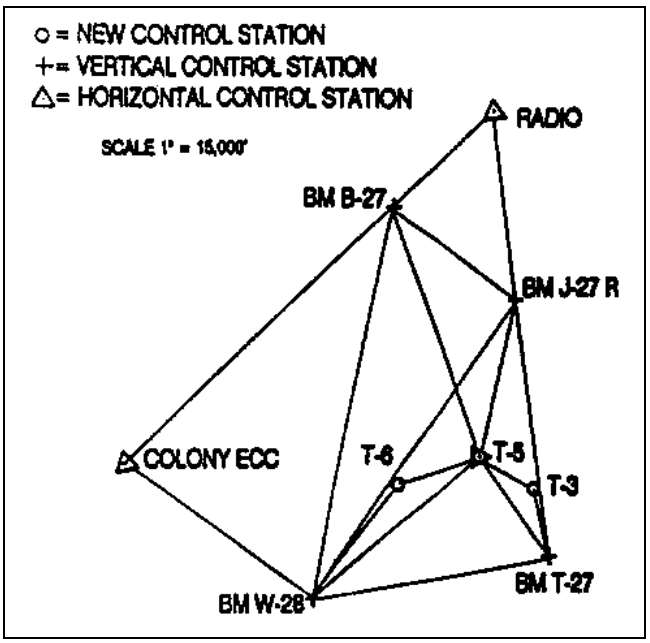



**Figure D-17. (Concluded)**

support digital mapping of the Upper Saginaw River. Saginaw's function was to provide horizontal control in this area for mapping purposes. Six points (3 pairs) were established, see Figure D-17. Control was brought in from two First-Order NGS horizontal control stations, stations Jonas and Parrish.

*c.* Four Ashtech Dual Frequency (L1/L2) GPS receivers and antennas with ground planes were used for this project.

*d.* Prior to any data collection, a preplanning survey was conducted to determine any obstructions (see Figure D-18) and examine existing control. Control station Jonas and Parrish had some sinking problems due to thawing ground. Station Jonas was readjusted during the survey but station Parrish was not.

*e.* A satellite visibility chart was run to determine occupation times for each session on both day 083 and day 084. The chart included the number of satellites and PDOP for the project area. The charts were run with an elevation mask of 20 deg (see Figure D-19) and 25 deg (see Figure D-20).

*f.* There were three survey sessions held on day 083 and one on day 084. Table D-5 lists sessions, occupation times, and stations occupied for day 083 and Table D-6 lists day 084 occupation times and stations.

## D-11. Actual Survey

The survey was performed as planned, with three sessions on day 083 and one session on day 084. An observation log (see Figure D-21) for each station was recorded by the observer. This information was used during post-processing.

## D-12. Data Processing and Adjustment

*a.* The GPS baselines were processed using Ashtech baseline reduction software (GPPS). All four sessions were processed. An output file from this program is shown in Figure D-22. From these results, session 083 A and B and 084 seemed to be satisfactory. Session 083 C tagged all the float solutions except for the vector between 4008 and 4009. The plots for these vectors, between 4008 and 4009, appeared to have been affected by the ionosphere.

*b.* After baseline processing was completed, a loop closure was performed to show closures with known control (see Figure D-23) and one was performed to show closures with the unknown control stations.

*c.* Once the closures were completed, a free adjustment and a constrained adjustment were performed on all processed baselines for Julian days 083 and 084. Figure D-24 was the input file used for the free adjustment. The constrained adjustment held fixed station PARRISH's X,Y,Z and station JONAS' X,Y. The results of the constrained adjustment are listed in Figure D-25.

*d.* After the final adjustment of the data, CORPSCON was used to convert the station latitude and longitude to state plane coordinates. This file is listed in Figure D-26.

## D-13. Station Descriptions

Station descriptions with adjusted coordinates for each control station set were formulated. These are listed in Figure D-27.

" G.P.S. PREPLANNING SURVEY "

PROJECT: UPPER SAGINAW

STATION NAME: Hoyt RIGHT OF ENTRY YES DATE:

HORIZONTAL CONTROL: KNOWN ____ UNKNOWN ✓ (IF UNKNOWN GIVE APPROX. LAT/LONG)

IF KNOWN GIVE VALUES: DATUM ____ PROJECTION ____ ZONE ____

LATITUDE ____ NORTH ____

LONGITUDE ____ EAST ____

VERTICAL CONTROL: KNOWN ____ UNKNOWN ✓ (IF UNKNOWN GIVE APPROX. ELEV.)

IF KNOWN GIVE VALUES: DATUM ____ ELEV. FT. ____ METERS ____

OBSEVATION SITE: COMPLETE OBSTRUCTION POLAR MAP (SEE BELOW)

ACCESSABILITY: CAR/TRUCK ✓ HIKE ____ BOAT ✓

DISTANCE VEHICLE CAN BE PARKED TO STATION: ____

PRIVATE PROPERTY ____ PUBLIC PROPERTY ✓ KEY FOR GATE REQUIRED ____

NOTIFICATION OF PROPERTY OWNER REQUIRED PRIOR TO ACCESS NO

NAME: SAG. RIVER WALK IF YES PHONE # ____

OBSTRUCTION POLAR MAP:

INDICATE OBSTRUCTIONS:
EX. TREES, BUILDINGS,...
(SEE EXAMPLE ON BACK)

REMARKS:

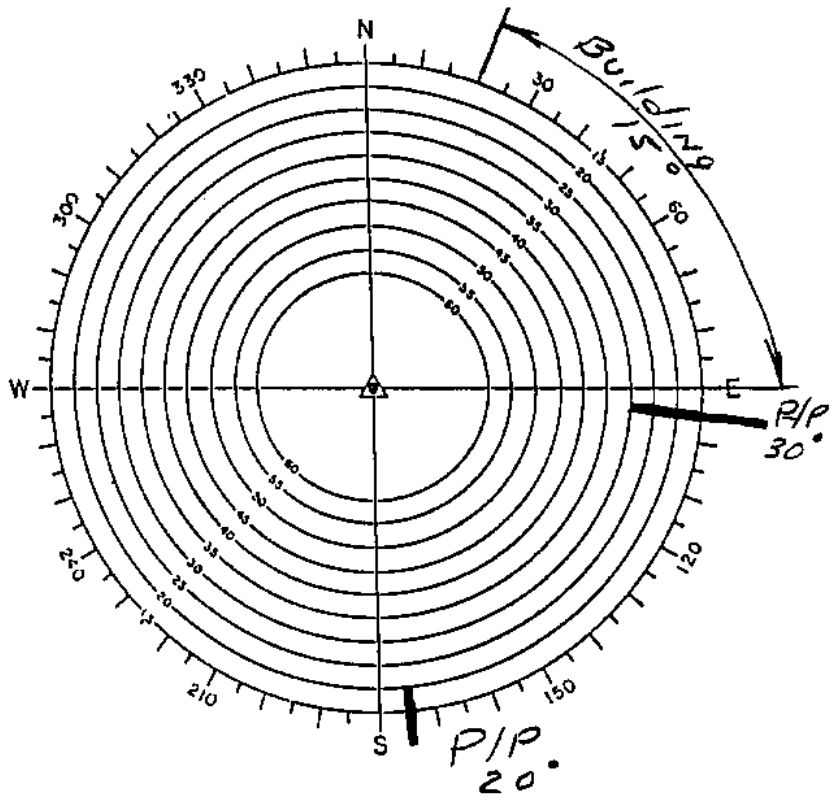



**Figure D-18. Preplanning survey, Upper Saginaw River project**

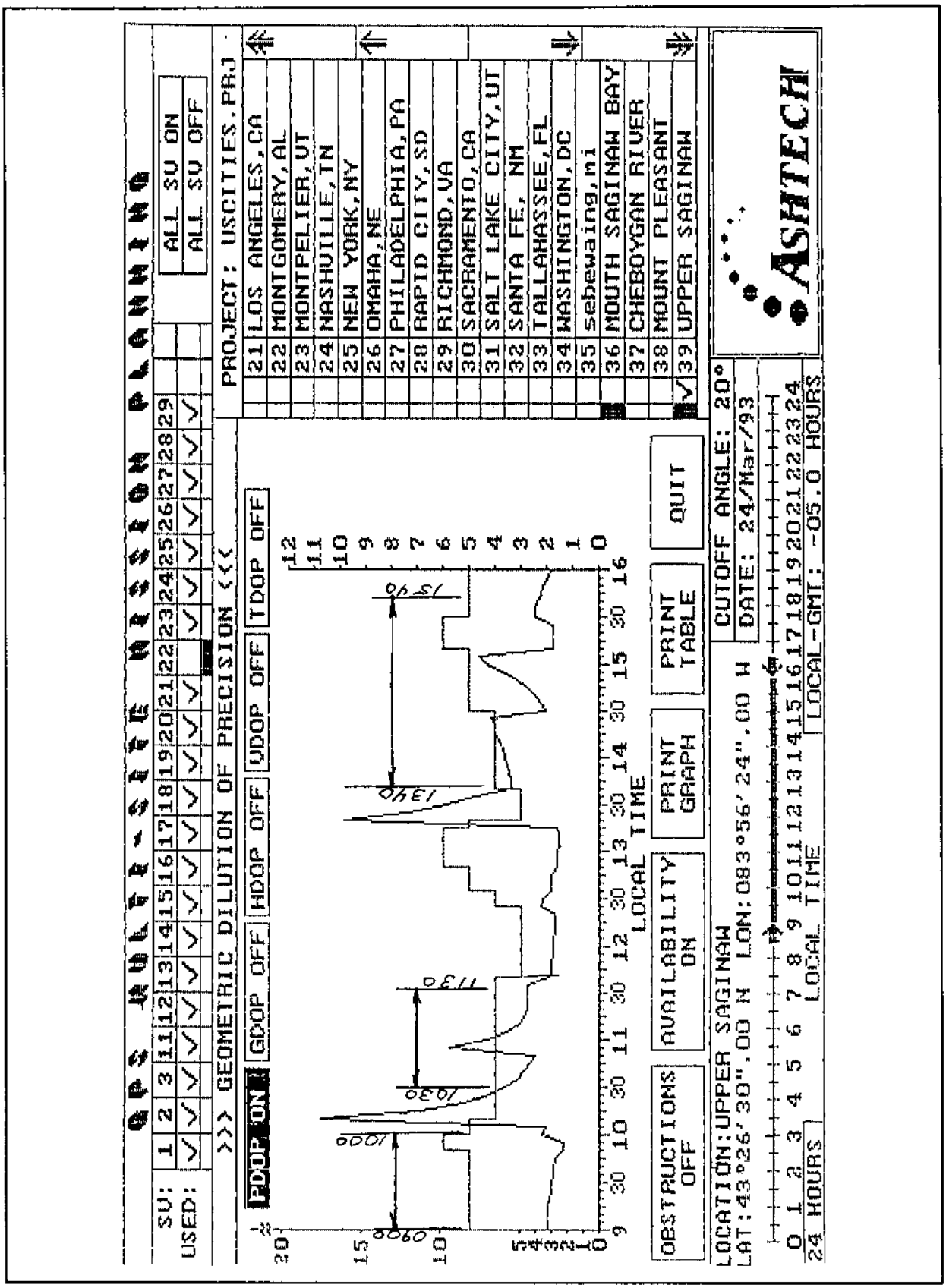



Figure D-19. Satellite visibility chart, elevation mask 20 deg

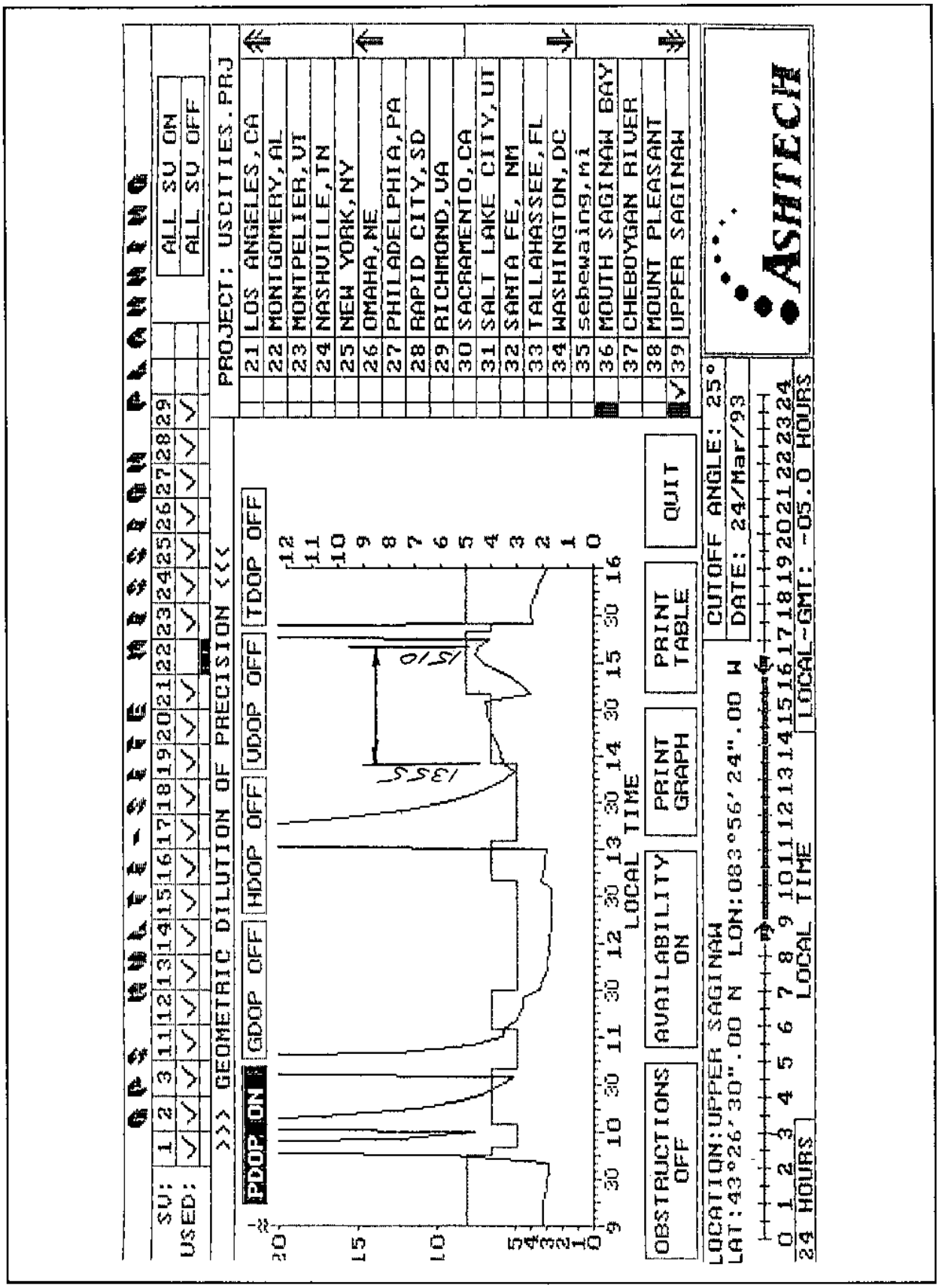



Figure D-20. Satellite visibility chart, elevation mask 25 deg

**Table D-5**
**Day 083**

| Session A<br>0900-1000 | Session B<br>1030-1130 | Session C<br>1340-1540 |
|---|---|---|
| HOYT | WICKES | WICKES |
| GENESSEE | RUST | RUST |
| HOLLAND | HOLLAND | JONAS |
| EWALD | EWALD | PARRISH |

**Table D-6**
**Day 084**

| Session A<br>1335-1535 |
|---|
| HOYT |
| GENESEE |
| JONAS |
| PARRISH |

CORPS OF ENGINEERS " GPS OBSERVATION LOG " SAGINAW AREA OFFICE

PROJECT SAG. RIVER LOCATION

OBSERVER NAME GREG DATE 3-24-93 JULIAN DATE 083

**********

SESSION "A"

STATION NAME: HOYT STATION # 4004

SKED.START 0900 ACTUAL START 0850 SKED.STOP 1000 ACTUAL STOP

ANTENNA HEIGHT: INCHES: BEFORE 59¼" AFTER 59¼" MEAN 59¼"

METERS: BEFORE 1.505m AFTER 1.505 MEAN 1.505 ✓

**********

SESSION "B"

STATION NAME: WICKES STATION # 4008

SKED.START 1030 ACTUAL START 1030 SKED.STOP 11:30 ACTUAL STOP 1130

ANTENNA HEIGHT: INCHES: BEFORE 62 3/16 AFTER 62 3/16 MEAN 62 3/16"

METERS: BEFORE 1.579 AFTER 1.579 MEAN 1.579 ✓

**********

SESSION "C"

STATION NAME: WICKES STATION # 4008

SKED.START 1340 ACTUAL START 1335 SKED.STOP 1540 ACTUAL STOP 1540

ANTENNA HEIGHT: INCHES: BEFORE 64 3/8" AFTER 64 3/8" MEAN 64 3/8"

METERS: BEFORE 1.636 AFTER 1.636 MEAN 1.636 ✓

**********

SESSION "D"

STATION NAME: STATION #

SKED.START ACTUAL START SKED.STOP ACTUAL STOP

ANTENNA HEIGHT: INCHES: BEFORE AFTER MEAN

METERS: BEFORE AFTER MEAN

**********

RECEIVER INFORMATION

S/N 501 ANTENNA # 001 ANT. CABLE LENGTH 50' POWER SUPPLY 24V

GROUND PLANES USED YES L1 YES L2 YES

**********

COMMENTS:(WEATHER, PROBLEMS, OCCURENCES, ?)

SESSION "A" REC. SV #'s 01-12-15-20-21-23-25 (LOST #23 = 0910
" #12 - 0915
GAIN #14 - 0920)

SESSION "B" " " # 01-14-15-20-25-29 (LOST #15 - 1045
" #20 - 1120)

SESSION "C" " " # 03-14-18-19-25-28-29 (LOST #14 - 1350 OVER)

Figure D-21. Observation log, Upper Saginaw River project

```
Ashtech, Inc. GPPS-L          Program: LINECOMP          Version: 4.5.00
                            Fri Mar 26 10:34:33 1993

Project information
GPS Survey                  |25-character project name  [ The | is in column 26
. ]
0843A                       |5-character session name
Project information

Known-station parameters
00                          |Receiver identifier used in "LOGTIMES" file
000000                      |Project station number
1001                        |4-character short name
FIXED STATION               |25-character long name
503 003 005 _____________   |25-character comment field
0                           |Position extraction (0=below,1=U-file,2=proj. file
)
N  43 33 32.67131           |Latitude deg-min-sec  (g=good;b=bad)
E 276 11 32.13854           |E-Longitude deg-min-sec (g=good;b=bad)
W  83 48 27.86146           |W-Longitude deg-min-sec (g=good;b=bad)
   150.7356                 |Ellipsoidal height  (m) (g=good;b=bad)
     0.0000                 |North antenna offset(m)
     0.0000                 |East antenna offset (m)
  1.6990  0.1150  0.0000    |Vert antenna offset (m): slant/radius/added_offset
    20.0                    |Temperature (degrees C)
    50.0                    |Humidity (percent)
  1010.0                    |Pressure (millibars)
U1001A93.084                |Measurement filename (restricted to 24 characters)
Known-station parameters

Unknown-station parameters
00                          |Receiver identifier used in "LOGTIMES" file
000000                      |Project station number
4005                        |4-character short name
UNKNOWN STATION             |25-character long name
504 004 007 _____________   |25-character comment field
0                           |Position extraction (0=below,1=U-file,2=proj. file
)
N  43 26  1.65174           |Latitude deg-min-sec  (g=good;b=bad)
E 276  3 25.93899           |E-Longitude deg-min-sec (g=good;b=bad)
W  83 56 34.06101           |W-Longitude deg-min-sec (g=good;b=bad)
   149.5289                 |Ellipsoidal height  (m) (g=good;b=bad)
     0.0000                 |North antenna offset(m)
     0.0000                 |East antenna offset (m)
  1.6350  0.1150  0.0000    |Vert antenna offset (m): slant/radius/added_offset
    20.0                    |Temperature (degrees C)
    50.0                    |Humidity (percent)
  1010.0                    |Pressure (millibars)
U4005A93.084                |Measurement filename (restricted to 24 characters)
Unknown-station parameters
```

Figure D-22. Output file, Upper Saginaw River project (Ashtech) (Sheet 1 of 5)

```
Run-time parameters
    1                       |First epoch to process
   -1                       |Final epoch to process (-1 = last available)
20.0                        |Elevation cutoff angle (degrees)
1                           |Data to process (0=Wdln;1=L1;2=L2;3=L1c;6=RpdSt)
0.010000                    |Convergence criterion (meters)
00 00 00 00 00 00 00        |Omit these satellites (up to 7)
10                          |Maximum iterations for tlsq and dlsq
00 00 00 00 00 00 00        |Forbidden reference SVs (up to 7)
yes                         |Apply tropo delay correction
Run-time parameters

LINECOMP 4.5.00 12/11/92

FIXED U-File from L1 only receiver.
UNKWN U-File from L1 only receiver.

FIXED U-File used BROADCAST orbits.
UNKWN U-File used BROADCAST orbits.

Common start of two UFILES: 1993/03/25 18:35:60.00
Common end   of two UFILES: 1993/03/25 20:32:60.00
    Selected first epoch:  1
    Selected last  epoch:  352
For SV 11 there are   221 triple-difference measurements.
For SV 18 there are   351 triple-difference measurements.
For SV 19 there are   351 triple-difference measurements.
For SV 27 there are    73 triple-difference measurements.
For SV 28 there are   348 triple-difference measurements.
For SV 29 there are   338 triple-difference measurements.
Epoch interval (seconds): 20.000000


THE TRIPLE DIFFERENCE SOLUTION (L1)
Measure of geometry: 0.640415
num_meas =  1329        num_used =  1323         rms_resid = 0.002595(m)
Post-Fit Chisq =  3459.383          NDF      =    12.250


  Sigmax (m):       0.870234
  Sigmay (m):       0.572256
  Sigmaz (m):       0.270963
  x     y     z
x 1.00
y 0.71y 1.00
z-0.40z-0.59z 1.00

del_station: 0.005074 0.001394 -0.000650
     Station1: FIXED STATION              Station2: UNKNOWN STATION

                (00000)    (1001)                    (00000)    (4005)
```

Figure D-22. (Sheet 2 of 5)

```
 Latitude:  43.55907536  43 33 32.67131          43.43379221  43 26  1.65195

 E-Long  : 276.19226071 276 11 32.13854         276.05720501 276  3 25.93803

 W-Long  :  83.80773929  83 48 27.86146          83.94279499  83 56 34.06197

 E-Height: 150.7356                              149.5416

 Baseline vector:     -9839.2603    -10690.9170    -10098.3296

 Mark1_xyz  :   499359.2995  -4602470.6194   4372824.2683
 Az1 El1 D1 :      218.17046       -0.0834     17694.1519
 E1 N1 U1   :   -10912.4583    -13919.7439        -1.1940
 Mark2_xyz  :   489520.0392  -4613161.5364   4362725.9387
 Az2 El2 D2 :       38.07750       -0.0757     17694.1519
 E2 N2 U2   :    10935.0401     13919.4351         1.1940

Double-Difference Epochs:
  Prn:  11  Start epoch:  132  End epoch:  352
  Prn:  18  Start epoch:    2  End epoch:  352
  Prn:  19  Start epoch:    2  End epoch:  352
  Prn:  27  Start epoch:  280  End epoch:  352
  Prn:  28  Start epoch:    5  End epoch:  352
  Prn:  29  Start epoch:    2  End epoch:  339


THE FLOAT DOUBLE DIFFERENCE SOLUTION (L1)
Measure of geometry: 0.103203     Wavelength = 0.190294 (m/cycle)
num_meas =  1332        num_used =  1317         rms_resid = 0.004061(m)
Post-Fit Chisq =    42.171           NDF      =    12.194

Reference SV: 18
  SV     Ambiguity        FIT    Meas      SV     Ambiguity        FIT    Meas
  11      22406589.878f  0.024    211      19      21161231.999f  0.018    350
  27      10785453.076f  0.024     72      28      28836460.832f  0.022    348
  29       5129536.945f  0.021    336

  Sigmax (m):      0.015558
  Sigmay (m):      0.010159
  Sigmaz (m):      0.004803
  SigmaN (cy):     0.075992
  SigmaN (cy):     0.018403
  SigmaN (cy):     0.034642
  SigmaN (cy):     0.089934
  SigmaN (cy):     0.033807
  x     y     z     N     N     N     N     N
x 1.00
y 0.72y 1.00
z-0.50z-0.65z 1.00
N 0.97N 0.72N-0.59N 1.00
N-0.10N 0.42N-0.05N-0.05N 1.00
```

Figure D-22. (Sheet 3 of 5)

```
N-0.31N 0.26N-0.05N-0.26N 0.67N 1.00
N 0.99N 0.76N-0.52N 0.98N-0.00N-0.24N 1.00
N 0.89N 0.57N-0.60N 0.93N-0.11N-0.32N 0.90N 1.00

del_station: 0.000000 0.000000 0.000000
     Station1: FIXED STATION              Station2: UNKNOWN STATION

                (00000)    (1001)                    (00000)    (4005)
 Latitude:  43.55907536  43 33 32.67131          43.43379217  43 26  1.65179

 E-Long  : 276.19226071 276 11 32.13854         276.05720515 276  3 25.93854

 W-Long  :  83.80773929  83 48 27.86146          83.94279485  83 56 34.06146

 E-Height: 150.7356                              149.5272

 Baseline vector:     -9839.2497    -10690.9086    -10098.3429

 Mark1_xyz  :   499359.2995  -4602470.6194   4372824.2683
 Az1 El1 D1 :      218.17042       -0.0834     17694.1485
 E1 N1 U1   :   -10912.4468    -13919.7486        -1.2084
 Mark2_xyz  :   489520.0498  -4613161.5280   4362725.9254
 Az2 El2 D2 :       38.07746       -0.0756     17694.1485
 E2 N2 U2   :    10935.0287     13919.4398         1.2084


AMBIGUITY RESOLUTION
                          1          2          3          4
Abs Contrast          0.008      0.000      0.000      0.000
Contrast                       100.000    100.000    100.000
Change Chi2          38.426   4588.301   4624.842   5296.077
Bias S18:11        22406590   22406591   22406589   22406590
Bias S18:19        21161232   21161232   21161232   21161232
Bias S18:27        10785453   10785453   10785453   10785454
Bias S18:28        28836461   28836462   28836460   28836461
Bias S18:29         5129537    5129537    5129537    5129537
NDF=136.7000 Chi2=42.1709


THE FIXED DOUBLE DIFFERENCE SOLUTION (L1)
Measure of geometry: 0.030142     Wavelength = 0.190294 (m/cycle)
num_meas =  1332        num_used =  1315         rms_resid = 0.005514(m)
Post-Fit Chisq =    77.434           NDF      =    12.176

Reference SV: 18                    Integer Search Ratio =  100.000
  SV     Ambiguity        FIT    Meas      SV     Ambiguity        FIT    Meas
  11      22406590.000X  0.031   213       19      21161232.000X  0.029   350
  27      10785453.000X  0.053    65       28      28836461.000X  0.025   349
  29       5129537.000X  0.024   338

  Sigmax (m):       0.002257
```

Figure D-22. (Sheet 4 of 5)

```
   Sigmay (m):      0.005658
   Sigmaz (m):      0.004546
   x     y     z
x 1.00
y 0.19y 1.00
z 0.12z-0.72z 1.00

del_station: 0.000016 0.000949 -0.000715
     Station1: FIXED STATION              Station2: UNKNOWN STATION

                (00000)    (1001)                    (00000)    (4005)
 Latitude:  43.55907536  43 33 32.67131          43.43379220  43 26  1.65191

 E-Long  : 276.19226071 276 11 32.13854         276.05720552 276  3 25.93986

 W-Long  :  83.80773929  83 48 27.86146          83.94279448  83 56 34.06014

 E-Height: 150.7356                              149.5220

 Baseline vector:     -9839.2208    -10690.8991    -10098.3438

 Mark1_xyz  :   499359.2995  -4602470.6194   4372824.2683
 Az1 El1 D1 :      218.17035       -0.0835     17694.1272
 E1 N1 U1   :   -10912.4172    -13919.7449        -1.2136
 Mark2_xyz  :   489520.0787  -4613161.5185   4362725.9246
 Az2 El2 D2 :       38.07739       -0.0756     17694.1272
 E2 N2 U2   :    10934.9990     13919.4360         1.2136
Fri Mar 26 10:39:26 1993
```

Figure D-22. (Sheet 5 of 5)

```
 PROGRAM SHOOTER
Input: FILLNET.IN                          Output: 083084aa.lop


STARTING STATION NAME: 1001
 LINE FROM            TO                      DX          DY          DZ         LENGTH
   1  1001            4008      0833C  -11172.423 -14312.145 -13760.192  22781.646
  17  4008            4009      0833B    -412.530   1492.440   1614.982   2237.348
  14  4007            4009      0833B    -313.662   -602.201   -613.237    914.926
  11  4006            4007      0833A    -864.616   -467.386   -388.225   1056.754
   9  4006            4004      0833A     628.445    613.864    569.761   1047.091
  24  4005            4004      0843A      60.920   -445.464   -475.513    654.417
  20  1001            4005      0843A   -9839.221 -10690.899 -10098.344  17694.127

      STATION            LATITUDE          LONGITUDE        ELEV.        GH
      1001               43 33 32.67152    83 48 27.85821   150.615      0.000
      4008               43 23 18.39708    83 57 49.93702   146.842      0.000
      4009               43 24 30.42613    83 58  1.19491   146.545      0.000
      4007               43 24 57.46166    83 57 44.51670   156.913      0.000
      4006               43 25 14.92267    83 57  4.10971   152.264      0.000
      4004               43 25 40.45135    83 56 33.44979   148.694      0.000
      4005               43 26  1.65131    83 56 34.05326   149.238      0.000
      1001               43 33 32.67072    83 48 27.85454   150.452      0.000

 TRAVERSE LENGTH =  46.386 kilometers
 MISCLOSURES (LAT., LON., ELEV., meters):   -0.025  -0.082  -0.163
                                          LOOP MISCLOSURE =    4.0 ppm
    Since geoid heights are not given, the
    computed elevations may be seriously in error.


STARTING STATION NAME: 1002
 LINE FROM            TO                      DX          DY          DZ         LENGTH
  23  1002            4005      0843A    7853.486 -20463.167 -22275.296  31250.716
  10  4006            4005      0833A     567.529   1059.329   1045.274   1592.754
  12  4006            4007      0833B    -864.618   -467.386   -388.229   1056.757
  16  4008            4007      0833B     -98.867   2094.641   2228.220   3059.781
  18  4009            4008      0833C     412.552  -1492.436  -1614.997   2237.360
  13  4006            4009      0833B   -1178.280  -1069.587  -1001.466   1880.238
   9  4006            4004      0833A     628.445    613.864    569.761   1047.091
  24  4005            4004      0843A      60.920   -445.464   -475.513    654.417
   8  4005            4007      0833A   -1432.144  -1526.716  -1433.499   2537.088
  14  4007            4009      0833B    -313.662   -602.201   -613.237    914.926
   5  1002            4009      0833C    6107.640 -22591.898 -24322.208  33753.028

      STATION            LATITUDE          LONGITUDE        ELEV.        GH
      1002               43 42 37.45123    84 00 46.44187   162.300      0.000
      4005               43 26  1.65174    83 56 34.06100   149.529      0.000
      4006               43 25 14.92309    83 57  4.11762   152.555      0.000
      4007               43 24 57.46199    83 57 44.52470   157.201      0.000
      4008               43 23 18.39740    83 57 49.94506   147.130      0.000
```

**Figure D-23. Loop closure, Upper Saginaw River project (Continued)**

```
     4009                43 24 30.42676    83 58  1.20394    146.844      0.000
     4006                43 25 14.92339    83 57  4.11865    152.566      0.000
     4004                43 25 40.45206    83 56 33.45874    148.995      0.000
     4005                43 26  1.65202    83 56 34.06221    149.540      0.000
     4007                43 24 57.46234    83 57 44.52579    157.216      0.000
     4009                43 24 30.42681    83 58  1.20400    146.848      0.000
     1002                43 42 37.45140    84 00 46.44218    162.570      0.000

TRAVERSE LENGTH =  79.984 kilometers
MISCLOSURES (LAT., LON., ELEV., meters):    0.005   0.007   0.270
                                          LOOP MISCLOSURE =   3.4 ppm
   Since geoid heights are not given, the
   computed elevations may be seriously in error.
```

**Figure D-23. (Concluded)**

```
                                        FILLNET.IN
6378137.0   298.2572221  W    Y A 50 Y N N N N
Fillnet Input File  083084 FREE ADJ      43.5  83.9
      1001            43 33 32.67152  083 48 27.85821   150.615
    1    0
      4008            43 23 18.39709  083 57 49.93704   146.842
    2    0
      4009            43 24 30.42636  083 58  1.19634   146.561
    3    0
FFF   1002            43 42 37.45123  084  0 46.44187   162.300
    4    0
      4004            43 25 40.44276  083 56 33.45850   148.717
    5    0
      4005            43 26  1.64290  083 56 34.06171   149.245
    6    0
      4007            43 24 57.45316  083 57 44.52581   156.933
    7    0
      4006            43 25 14.91409  083 57  4.11839   152.287
    8    0
*
  24 3 510  510 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
    4 1001            4008     0833C  -11172.423 -14312.145 -13760.192  610201020
    1    2
    4 1001            4009     0833C  -11584.984 -12819.715 -12145.194  610201020
    1    3
    4 1002            1001     0833C   17692.643  -9772.176 -12177.017  610201020
    4    1
    4 1002            4008     0833C    6520.196 -24084.335 -25937.204  610201020
    4    2
    4 1002            4009     0833C    6107.640 -22591.898 -24322.208  610201020
    4    3
    4 4004            4005     0833A     -60.916    445.465    475.513
    5    6
    4 4004            4007     0833A   -1493.060  -1081.250   -957.986
    5    7
    4 4005            4007     0833A   -1432.144  -1526.716  -1433.499
    6    7
    4 4006            4004     0833A     628.445    613.864    569.761
    8    5
    4 4006            4005     0833A     567.529   1059.329   1045.274
    8    6
    4 4006            4007     0833A    -864.616   -467.386   -388.225
    8    7
    4 4006            4007     0833B    -864.618   -467.386   -388.229
    8    7
    4 4006            4009     0833B   -1178.280  -1069.587  -1001.466
    8    3
    4 4007            4009     0833B    -313.662   -602.201   -613.237
    7    3
    4 4008            4006     0833B     765.751   2562.026   2616.450
    2    8
    4 4008            4007     0833B     -98.867   2094.641   2228.220
    2    7
    4 4008            4009     0833B    -412.530   1492.440   1614.982
    2    3
    4 4009            4008     0833C     412.552  -1492.436  -1614.997
    3    2
    4 1001            4004     0843A   -9778.301 -11136.364 -10573.856
```

**Figure D-24. Input file for free adjustment, Upper Saginaw River project (Continued)**

FILLNET.IN

```
1    5
4 1001            4005      0843A   -9839.221 -10690.899 -10098.344
1    6
4 1002            1001      0843A   17692.725  -9772.257 -12176.953
4    1
4 1002            4004      0843A    7914.403 -20908.632 -22750.807
4    5
4 1002            4005      0843A    7853.486 -20463.167 -22275.296
4    6
4 4005            4004      0843A      60.920   -445.464   -475.513
6    5
```

Figure D-24. (Concluded)

```
 PROGRAM FILLNET, Version 3.0.00
 LICENSED TO: ASHTECH INC.


 Fillnet Input File  083084 CONSTRAINED      43.5    83.9

 a =  6378137.000    1/f =  298.2572221   W      Longitude positive WE
ST

 PRELIMINARY COORDINATES:
                         LAT.              LON.         ELEV.    G.H.  CON
STR.

   1  FF     1001 43 33 32.66675   83 48 27.86095    150.615   0.000
   2         4008 43 23 18.39709   83 57 49.93704    146.842   0.000
   3         4009 43 24 30.42636   83 58  1.19634    146.561   0.000
   4  FFF    1002 43 42 37.45123   84  0 46.44187    162.300   0.000
   5         4004 43 25 40.44276   83 56 33.45850    148.717   0.000
   6         4005 43 26  1.64290   83 56 34.06171    149.245   0.000
   7         4007 43 24 57.45316   83 57 44.52581    156.933   0.000
   8         4006 43 25 14.91409   83 57  4.11839    152.287   0.000

 GROUP 1, NO. OF VECTORS AND BIAS CONSTRAINTS:

  24       0.000  0.001    0.000  0.001    0.000  0.000    0.000  0.000

 VECTORS:
                      DX          DY          DZ       LENGTH    ERROR CODES

 1001    4008  -11172.423 -14312.145 -13760.192  22781.646  6102.0 102.
0  4
 1001    4009  -11584.984 -12819.715 -12145.194  21120.196  6102.0 102.
0  4
 1002    1001   17692.643  -9772.176 -12177.017  23596.711  6102.0 102.
0  4
 1002    4008    6520.196 -24084.335 -25937.204  35990.370  6102.0 102.
0  4
 1002    4009    6107.640 -22591.898 -24322.208  33753.028  6102.0 102.
0  4
 4004    4005     -60.916    445.465    475.513    654.418  3 51.0  51.
0  4
 4004    4007   -1493.060  -1081.250   -957.986   2077.515  3 51.0  51.
0  4
 4005    4007   -1432.144  -1526.716  -1433.499   2537.088  3 51.0  51.
0  4
 4006    4004     628.445    613.864    569.761   1047.091  3 51.0  51.
0  4
 4006    4005     567.529   1059.329   1045.274   1592.754  3 51.0  51.
0  4
 4006    4007    -864.616   -467.386   -388.225   1056.754  3 51.0  51.
0  4
```

**Figure D-25. Results of constrained adjustment, Upper Saginaw River project (Sheet 1 of 6)**

```
 4006   4007     -864.618   -467.386   -388.229   1056.757  3 51.0  51.
0  4
 4006   4009    -1178.280  -1069.587  -1001.466   1880.238  3 51.0  51.
0  4
 4007   4009     -313.662   -602.201   -613.237    914.926  3 51.0  51.
0  4
 4008   4006      765.751   2562.026   2616.450   3741.145  3 51.0  51.
0  4
 4008   4007      -98.867   2094.641   2228.220   3059.781  3 51.0  51.
0  4
 4008   4009     -412.530   1492.440   1614.982   2237.348  3 51.0  51.
0  4
 4009   4008      412.552  -1492.436  -1614.997   2237.360  3 51.0  51.
0  4
 1001   4004    -9778.301 -11136.364 -10573.856  18205.499  3 51.0  51.
0  4
 1001   4005    -9839.221 -10690.899 -10098.344  17694.127  3 51.0  51.
0  4
 1002   1001    17692.725  -9772.257 -12176.953  23596.773  3 51.0  51.
0  4
 1002   4004     7914.403 -20908.632 -22750.807  31896.832  3 51.0  51.
0  4
 1002   4005     7853.486 -20463.167 -22275.296  31250.716  3 51.0  51.
0  4
 4005   4004       60.920   -445.464   -475.513    654.417  3 51.0  51.
0  4

  SHIFTS:
    1   0.000   0.000   0.102
    2  -0.190  -0.260   0.238
    3  -0.181  -0.230   0.226
    4   0.000   0.000   0.000
    5   0.097  -0.045   0.222
    6   0.095  -0.047   0.238
    7   0.091  -0.049   0.223
    8   0.095  -0.051   0.222

 ADJUSTED VECTORS, GROUP 1:
                              DX,DY,DZ   V       DN,DE,DU   v      v'

 1001   4008      0833C    -11172.608 -0.063  -18960.149  0.017   0.3
                           -14312.293 -0.093  -12630.231 -0.073  -1.1
                           -13760.130  0.105     -10.059  0.135   2.0

 1001   4009      0833C    -11585.141 -0.039  -16736.980  0.014   0.2
                           -12819.845 -0.085  -12881.834 -0.048  -0.8
                           -12145.133  0.095      -6.620  0.124   2.0

 1002   1001      0833C     17692.745  0.058  -16815.857 -0.014  -0.2
                            -9772.339 -0.070   16554.120  0.051   0.7
                           -12177.068  0.052      30.106  0.090   1.3
```

Figure D-25. (Sheet 2 of 6)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1002 | 4008 | 0833C | 6520.137 | 0.019 | -35776.006 | 0.007 | 0.1 |
| | | | -24084.632 | -0.149 | 3923.889 | 0.003 | 0.0 |
| | | | -25937.198 | 0.152 | 20.048 | 0.214 | 2.1 |
| 1002 | 4009 | 0833C | 6107.605 | 0.038 | -33552.837 | 0.000 | 0.0 |
| | | | -22592.184 | -0.148 | 3672.286 | 0.022 | 0.2 |
| | | | -24322.201 | 0.144 | 23.486 | 0.208 | 2.2 |
| 4004 | 4005 | 0833A | -60.916 | -0.001 | 654.286 | -0.000 | -0.0 |
| | | | 445.467 | -0.000 | -13.234 | -0.001 | -0.2 |
| | | | 475.516 | 0.000 | 1.327 | 0.000 | 0.0 |
| 4004 | 4007 | 0833A | -1493.074 | -0.001 | -1325.757 | -0.001 | -0.2 |
| | | | -1081.252 | 0.001 | -1599.518 | -0.001 | -0.2 |
| | | | -957.990 | -0.002 | 5.347 | -0.002 | -0.3 |
| 4005 | 4007 | 0833A | -1432.158 | 0.000 | -1980.043 | -0.000 | -0.0 |
| | | | -1526.719 | 0.002 | -1586.285 | 0.000 | 0.0 |
| | | | -1433.505 | -0.002 | 4.020 | -0.003 | -0.4 |
| 4006 | 4004 | 0833A | 628.451 | -0.000 | 787.486 | -0.000 | -0.1 |
| | | | 613.865 | -0.001 | 690.124 | -0.000 | -0.1 |
| | | | 569.763 | 0.000 | -2.121 | 0.001 | 0.1 |
| 4006 | 4005 | 0833A | 567.535 | -0.002 | 1441.772 | -0.000 | -0.1 |
| | | | 1059.333 | -0.001 | 676.890 | -0.002 | -0.3 |
| | | | 1045.278 | 0.000 | -0.794 | 0.001 | 0.1 |
| 4006 | 4007 | 0833A | -864.623 | -0.001 | -538.271 | -0.001 | -0.3 |
| | | | -467.387 | 0.000 | -909.394 | -0.001 | -0.1 |
| | | | -388.227 | -0.002 | 3.227 | -0.002 | -0.2 |
| 4006 | 4007 | 0833B | -864.623 | 0.001 | -538.271 | 0.001 | 0.3 |
| | | | -467.387 | 0.000 | -909.394 | 0.001 | 0.2 |
| | | | -388.227 | 0.002 | 3.227 | 0.001 | 0.2 |
| 4006 | 4009 | 0833B | -1178.293 | -0.003 | -1372.338 | 0.002 | 0.3 |
| | | | -1069.590 | 0.001 | -1285.281 | -0.002 | -0.3 |
| | | | -1001.467 | 0.001 | -8.729 | 0.000 | 0.0 |
| 4007 | 4009 | 0833B | -313.670 | -0.004 | -834.066 | 0.000 | 0.1 |
| | | | -602.203 | 0.001 | -375.887 | -0.004 | -0.5 |
| | | | -613.240 | -0.000 | -11.955 | -0.001 | -0.1 |
| 4008 | 4006 | 0833B | 765.761 | -0.006 | 3595.507 | 0.001 | 0.2 |
| | | | 2562.037 | -0.001 | 1033.678 | -0.006 | -0.7 |
| | | | 2616.464 | 0.002 | 12.167 | 0.002 | 0.2 |
| 4008 | 4007 | 0833B | -98.862 | -0.004 | 3057.236 | 0.003 | 0.4 |
| | | | 2094.651 | -0.002 | 124.284 | -0.005 | -0.6 |

Figure D-25. (Sheet 3 of 6)

```
                              2228.237  0.005      15.393  0.005   0.6

4008   4009      0833B       -412.532 -0.007    2223.169  0.004   0.7
                             1492.448 -0.002    -251.603 -0.007  -1.0
                             1614.997  0.006       3.438  0.004   0.6

4009   4008      0833C        412.532 -0.015   -2223.169  0.006   1.2
                            -1492.448 -0.002     251.603 -0.015  -1.9
                            -1614.997  0.009      -3.438  0.007   0.9

1001   4004      0843A      -9778.397  0.005  -14577.156 -0.004  -0.1
                           -11136.390  0.014  -10906.429  0.006   0.2
                           -10573.904 -0.017      -0.012 -0.022  -0.8

1001   4005      0843A      -9839.312  0.007  -13922.870 -0.003  -0.1
                           -10690.923  0.013  -10919.663  0.009   0.3
                           -10098.389 -0.016       1.314 -0.020  -0.8

1002   1001      0843A      17692.745 -0.024  -16815.857  0.001   0.0
                            -9772.339  0.011   16554.120 -0.022  -0.7
                           -12177.068 -0.012      30.106 -0.019  -0.5

1002   4004      0843A       7914.349  0.002  -31393.013  0.001   0.0
                           -20908.729  0.036    5647.691  0.006   0.1
                           -22750.972 -0.032      30.094 -0.048  -1.0

1002   4005      0843A       7853.433  0.002  -30738.727  0.003   0.1
                           -20463.262  0.036    5634.457  0.005   0.1
                           -22275.456 -0.030      31.421 -0.046  -1.0

4005   4004      0843A         60.916 -0.003    -654.286 -0.000  -0.1
                            -445.467 -0.001      13.234 -0.003  -0.4
                            -475.516 -0.000      -1.327  0.000   0.0

S.E. OF UNIT WEIGHT =      0.843

NUMBER OF -
  OBS. EQUATIONS              74
  UNKNOWNS                    23
  DEGREES OF FREEDOM          51
  ITERATIONS                   0


GROUP  1 ROT. ANGLES (sec.) AND SCALE DIFF. (ppm):

HOR. SYSTEM          0.000   0.000   0.657   5.277
STD. ERRORS          0.001   0.001   0.166   0.804
XYZ SYSTEM           0.051  -0.473   0.452

ADJUSTED POSITIONS:
```

Figure D-25. (Sheet 4 of 6)

| | | LAT. | LON. | ELEV. | STD. ERRORS (m) | | |
|---|---|---|---|---|---|---|---|
| 1 | 1001 | 43 33 32.66675 | 83 48 27.86095 | 150.717 | 0.000 | 0.000 | 0.019 |
| 2 | 4008 | 43 23 18.39093 | 83 57 49.94860 | 147.080 | 0.024 | 0.024 | 0.019 |
| 3 | 4009 | 43 24 30.42050 | 83 58 1.20657 | 146.787 | 0.022 | 0.023 | 0.019 |
| 4 | 1002 | 43 42 37.45123 | 84 0 46.44187 | 162.300 | 0.000 | 0.000 | 0.000 |
| 5 | 4004 | 43 25 40.44591 | 83 56 33.46051 | 148.939 | 0.020 | 0.020 | 0.019 |
| 6 | 4005 | 43 26 1.64599 | 83 56 34.06378 | 149.483 | 0.020 | 0.020 | 0.019 |
| 7 | 4007 | 43 24 57.45612 | 83 57 44.52799 | 157.156 | 0.022 | 0.022 | 0.019 |
| 8 | 4006 | 43 25 14.91718 | 83 57 4.12068 | 152.509 | 0.021 | 0.021 | 0.019 |

ACCURACIES (m):

| | | D. LAT. | D. LON. | VERT. |
|---|---|---|---|---|
| 1001 | 4008 | 0.024 | 0.024 | 0.014 |
| 1001 | 4009 | 0.022 | 0.023 | 0.014 |
| 1002 | 1001 | 0.000 | 0.000 | 0.019 |
| 1002 | 4008 | 0.024 | 0.024 | 0.019 |
| 1002 | 4009 | 0.022 | 0.023 | 0.019 |
| 4004 | 4005 | 0.002 | 0.004 | 0.004 |
| 4004 | 4007 | 0.003 | 0.004 | 0.004 |
| 4005 | 4007 | 0.003 | 0.004 | 0.004 |
| 4006 | 4004 | 0.003 | 0.004 | 0.004 |
| 4006 | 4005 | 0.003 | 0.004 | 0.004 |
| 4006 | 4007 | 0.002 | 0.003 | 0.003 |
| 4006 | 4007 | 0.002 | 0.003 | 0.003 |
| 4006 | 4009 | 0.003 | 0.004 | 0.004 |
| 4007 | 4009 | 0.003 | 0.004 | 0.004 |
| 4008 | 4006 | 0.004 | 0.005 | 0.004 |
| 4008 | 4007 | 0.004 | 0.005 | 0.004 |
| 4008 | 4009 | 0.003 | 0.004 | 0.004 |
| 4009 | 4008 | 0.003 | 0.004 | 0.004 |
| 1001 | 4004 | 0.020 | 0.020 | 0.014 |
| 1001 | 4005 | 0.020 | 0.020 | 0.014 |
| 1002 | 1001 | 0.000 | 0.000 | 0.019 |
| 1002 | 4004 | 0.020 | 0.020 | 0.019 |
| 1002 | 4005 | 0.020 | 0.020 | 0.019 |
| 4005 | 4004 | 0.002 | 0.004 | 0.004 |

**********
**** ****

Figure D-25. (Sheet 5 of 6)

**** ESTIMATES OF PRECISION ****
**** ****
**** Based on the VECTOR ACCURACIES produced by ****
**** FILLNET ****
**** ****
**** This is a reasonable estimate of the accuracies ****
**** of the vectors in the network at 1 SIGMA. ****
**** ****
**********

| VECTOR | | LENGTH | PPM(h) | RATIO(h) | PPM(v) | RATIO(v) |
|---|---|---|---|---|---|---|
| 1001 | 4008 | 22781.793 | 1.5 | 1: 671215 | 0.6 | 1: 1627271 |
| 1001 | 4009 | 21120.326 | 1.5 | 1: 663584 | 0.7 | 1: 1508595 |
| 1002 | 1001 | 23596.882 | 0.0 | 1: 0 | 0.8 | 1: 1241941 |
| 1002 | 4008 | 35990.553 | 0.9 | 1: 1060382 | 0.5 | 1: 1894240 |
| 1002 | 4009 | 33753.209 | 0.9 | 1: 1060499 | 0.6 | 1: 1776485 |
| 4004 | 4005 | 654.421 | 6.8 | 1: 146333 | 6.1 | 1: 163605 |
| 4004 | 4007 | 2077.527 | 2.4 | 1: 415504 | 1.9 | 1: 519382 |
| 4005 | 4007 | 2537.102 | 2.0 | 1: 507420 | 1.6 | 1: 634275 |
| 4006 | 4004 | 1047.096 | 4.8 | 1: 209419 | 3.8 | 1: 261774 |
| 4006 | 4005 | 1592.761 | 3.1 | 1: 318552 | 2.5 | 1: 398190 |
| 4006 | 4007 | 1056.761 | 3.4 | 1: 293091 | 2.8 | 1: 352254 |
| 4006 | 4007 | 1056.761 | 3.4 | 1: 293091 | 2.8 | 1: 352254 |
| 4006 | 4009 | 1880.249 | 2.7 | 1: 376046 | 2.1 | 1: 470062 |
| 4007 | 4009 | 914.932 | 5.5 | 1: 182971 | 4.4 | 1: 228733 |
| 4008 | 4006 | 3741.164 | 1.7 | 1: 584269 | 1.1 | 1: 935291 |
| 4008 | 4007 | 3059.800 | 2.1 | 1: 477854 | 1.3 | 1: 764950 |
| 4008 | 4009 | 2237.364 | 2.2 | 1: 447472 | 1.8 | 1: 559341 |
| 4009 | 4008 | 2237.364 | 2.2 | 1: 447472 | 1.8 | 1: 559341 |
| 1001 | 4004 | 18205.594 | 1.6 | 1: 643665 | 0.8 | 1: 1300400 |
| 1001 | 4005 | 17694.218 | 1.6 | 1: 625585 | 0.8 | 1: 1263873 |
| 1002 | 1001 | 23596.882 | 0.0 | 1: 0 | 0.8 | 1: 1241941 |
| 1002 | 4004 | 31897.000 | 0.9 | 1: 1127729 | 0.6 | 1: 1678789 |
| 1002 | 4005 | 31250.879 | 0.9 | 1: 1104885 | 0.6 | 1: 1644783 |
| 4005 | 4004 | 654.421 | 6.8 | 1: 146333 | 6.1 | 1: 163605 |

Figure D-25. (Sheet 6 of 6)

```
                                        083084C.SPC
;Software: CORPSCON v3.01, Agency: CORPS OF ENGINEERS SAGINAW
;Project: UPPER SAGINAW MAPPING,
;Original Coordinates on NAD 83 Geographic Coordinates
;Translated Coordinates on NAD 83 State Plane Zone 2113,U.S. FOOT

1001 JONAS           ,13271491.47735,  750899.10875
4008 WICKS           ,13230401.67183,  688469.29439
4009 RUST            ,13229535.79827,  695757.90291
1002 PARRISH         ,13216876.80162,  805765.50958
4004 HOYT            ,13235976.88650,  702879.28348
4005 GENESSEE        ,13235921.56530,  705025.46304
4007 EWALD           ,13230753.74995,  698500.99009
4006 HOLLAND         ,13233727.24329,  700283.34945
```

**Figure D-26. CORPSCON file, Upper Saginaw River project**

U.S. ARMY ENGINEER DISTRICT - DETROIT

**GENERAL INFORMATION**

designation: HOYT
reference no. SAG-0613

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 24

**HORIZONTAL**

datum: NAD83
lat: 43° 25'40.44591" N
lon: 83° 56'33.46051" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 702,879.28 ft (US) N
X: 13,235,976.89 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

**HORIZONTAL ORIGIN**

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Source:

JONAS 1932
PARRISH

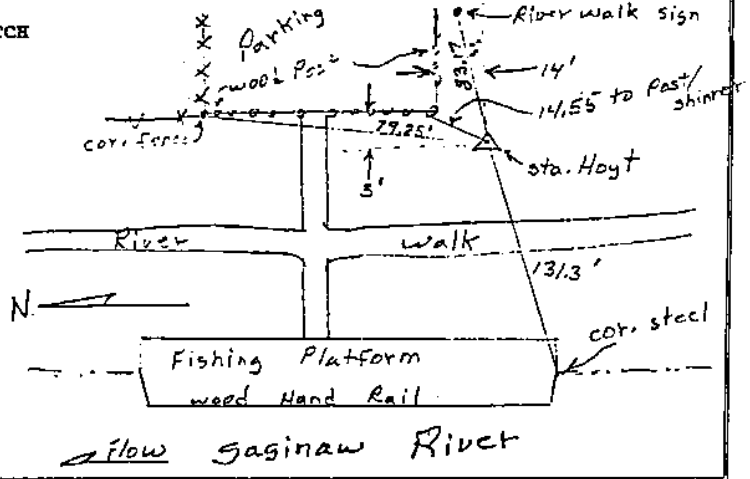
**MOST RECENT RECOVERY**
03/23/93 NEW

| VERTICAL | feet | meters |
|---|---|---|
| IGLD 1955: | 0.000 | 0.000 |
| IGLD 1985: | 0.000 | 0.000 |
| NAVD 1988: | 0.000 | 0.000 |
| NGVD 1929: | 0.000 | 0.000 |
| pt. source: | | |
| geoid. hgt: | 0.000 | 0.000 |

**PROPERTY OWNER**
firm:
P.O.C. RIVER WALK
telephone:
access: car, boat

**DESCRIPTION**
STATION HOYT IS A BRASS DISK SET IN A SIX-INCH-DIA. CONCRETE MONUMENT FLUSH WITH THE GROUND. STATION IS 14.55 FT. SOUTH-WEST OF POST AT THE SOUTHWEST CORNER OF THE PARKING LOT. STATION IS ON THE EAST SIDE OF THE SAGINAW RIVER BETWEEN THOMPSON ST. AND HOYT ST. AND ON THE WEST SIDE OF SOUTH WATER ST. TO REACH STATION FROM I-675, TAKE WASHINGTON ST. SOUTH TO HOYT ST., TURN RIGHT ON HOYT AND GO TO SOUTH WATER ST.. TURN RIGHT ON SOUTH WATER ST. AND PARKING LOT FOR RIVER WALK IS ON YOUR LEFT SIDE.

**SKETCH**




Ref # SAG-0613 **SURVEY CONTROL DATA** Desig: HOYT

Office of Record: Saginaw Area Office

Printed on 11/04/93

**Figure D-27. Descriptions of Stations Hoyt, Wickes, Eward, Rust, Holland, and Genesee (Sheet 1 of 6)**

U.S. ARMY ENGINEER DISTRICT - DETROIT

**GENERAL INFORMATION**

designation: WICKES
reference no. SAG-0610

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 25

**HORIZONTAL**

datum: NAD83
lat: 43° 23'18.39093" N
lon: 83° 57'49.94860" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 688,469.29 ft (US) N
X: 13,230,401.67 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

**HORIZONTAL ORIGIN**

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Source:

JONAS 1932
PARRISH

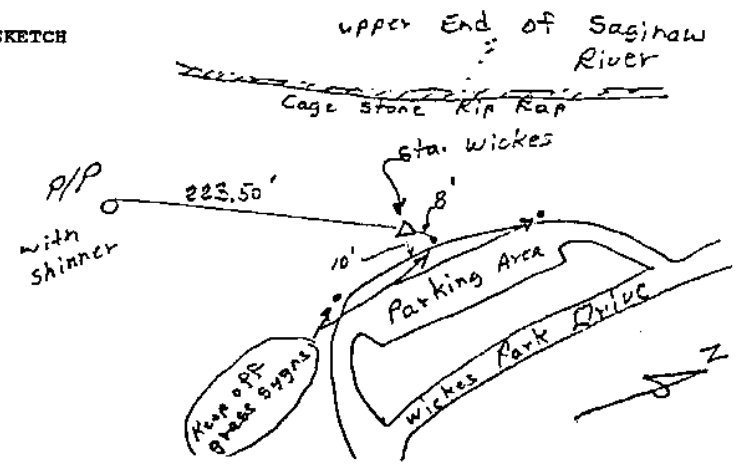
**MOST RECENT RECOVERY**
03/23/93 NEW

| VERTICAL | feet | meters |
|---|---|---|
| IGLD 1955: | 0.000 | 0.000 |
| IGLD 1985: | 0.000 | 0.000 |
| NAVD 1988: | 0.000 | 0.000 |
| NGVD 1929: | 0.000 | 0.000 |
| pt. source: | | |
| geoid. hgt: | 0.000 | 0.000 |

**PROPERTY OWNER**
firm:
P.O.C. WICKS PARK
telephone:
access: car, boat

**DESCRIPTION**
STATION WICKES IS AN ALUM. DISK IN A SIX-INCH-DIA. CONCRETE MONUMENT FLUSH WITH THE GROUND SURFACE. STATION IS AT THE VERY UPPER END OF THE SAGINAW RIVER ON THE EAST SIDE IN WICKS PARK. TO REACH STATION FROM THE INTERSECTION OF M-13 (WASHINGTON) AND I-675, GO SOUTH ON M-13 UNTIL YOU REACH WICKS PARK DRIVE, TURN RIGHT AND GO TO THE RIVER. STATION IS AT THE PARKING AREA WHERE WICKS PARK DRIVE TURNS TO THE NORTH.

**SKETCH**




Ref #. SAG-0610

# SURVEY CONTROL DATA

Desig: WICKES

Office of Record: Saginaw Area Office

*Printed on 11/04/93*

**Figure D-27. (Sheet 2 of 6)**

U.S. ARMY ENGINEER DISTRICT - DETROIT

**GENERAL INFORMATION**

designation: EWALD
reference no. SAG-0611

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 26

**HORIZONTAL**

datum: NAD83
lat: 43° 24'57.45612" N
lon: 83° 57'44.52799" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 698,500.99 ft (US) N
X: 13,230,753.75 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

**HORIZONTAL ORIGIN**

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Source:

JONAS 1932
PARRISH

**MOST RECENT RECOVERY**

03/23/93 NEW

| VERTICAL | feet | meters |
|---|---|---|
| IGLD 1955: | 0.000 | 0.000 |
| IGLD 1985: | 0.000 | 0.000 |
| NAVD 1988: | 0.000 | 0.000 |
| NGVD 1929: | 0.000 | 0.000 |
| pt. source: | | |
| geoid. hgt: | 0.000 | 0.000 |

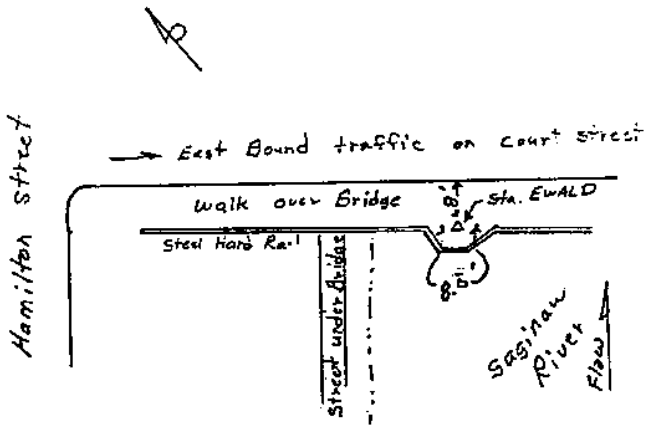
**PROPERTY OWNER**

firm:
P.O.C. ON BRIDGE
telephone:
access: , hike

**DESCRIPTION**

STATION EWALD IS A BRASS DISK SET INTO A CONCRETE SIDEWALK ON THE UPSTREAM SIDE OF THE COURT STREET BRIDGE OVER THE SAGINAW RIVER IN THE CITY OF SAGINAW. STATION IS 475 FT. (+-) WEST TO SOUTH HAMILTON STREET FROM STATION. STATION IS AT THE FIRST OBSERVATION PLATFORM FROM THE WEST SIDE OF THE BRIDGE. TO REACH COURT STREET BRIDGE FROM I-675, TAKE M-13 (WASHINGTON) SOUTH TO RUST DRIVE, TURN RIGHT AND IT TAKES YOU ACROSS THE COURT STREET BRIDGE AND STREET TURNS INTO COURT STREET.

**SKETCH**




Ref # SAG-0611

# SURVEY CONTROL DATA

Desig: EWALD

Office of Record: Saginaw Area Office

Printed on 11/04/93

**Figure D-27. (Sheet 3 of 6)**

U.S. ARMY ENGINEER DISTRICT - DETROIT

**GENERAL INFORMATION**

designation: RUST
reference no. SAG-0612

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 26

**HORIZONTAL**

datum: NAD83
lat: 43° 24'30.42050" N
lon: 83° 58' 1.20657" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 695,757.90 ft (US) N
X: 13,229,535.80 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

**HORIZONTAL ORIGIN**

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Source:

JONAS 1932
PARRISH

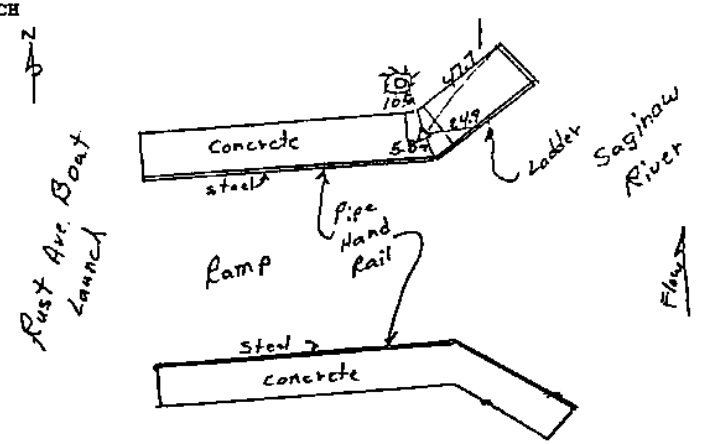
**MOST RECENT RECOVERY**
03/23/93 NEW

| VERTICAL | feet | meters |
|---|---|---|
| IGLD 1955: | 0.000 | 0.000 |
| IGLD 1985: | 0.000 | 0.000 |
| NAVD 1988: | 0.000 | 0.000 |
| NGVD 1929: | 0.000 | 0.000 |
| pt. source: | | |
| geoid. hgt: | 0.000 | 0.000 |

**PROPERTY OWNER**
firm: SAGINAW
P.O.C. BOAT LAUNCH
telephone:
access: car, boat

**DESCRIPTION**
STATION IS A BRASS DISK SET IN CONCRETE ON THE NORTH SIDE OF A BOAT LAUNCH RAMP (RUST AVE. BOAT LAUNCH) OWNED BY THE CITY OF SAGINAW. TO REACH STATION FROM THE RUST STREET BRIDGE (M-46) OVER THE SAGINAW RIVER, TAKE SOUTH HAMILTON SOUTH TO LEE STREET, GO EAST TO RIVER AND RUST AVE. BOAT LAUNCH IS AT THE END OF THE STREET. NOTE: THERE ARE TWO SIGNS DIRECTING YOU TO THE BOAT LAUNCH, LEE ST. & SOUTH HAMILTON, AND ONE NEAR THE BRIDGE ON THE WEST SIDE OF THE RIVER.

**SKETCH**




Ref # SAG-0612

# SURVEY CONTROL DATA

Desig: RUST

Office of Record: Saginaw Area Office

Printed on 11/04/93

Figure D-27. (Sheet 4 of 6)

U.S. ARMY ENGINEER DISTRICT - DETROIT

**GENERAL INFORMATION**

designation: HOLLAND
reference no. SAG-0608

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 25

**HORIZONTAL**

datum: NAD83
lat: 43° 25'14.91718" N
lon: 83° 57' 4.12068" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 700,283.35 ft (US) N
X: 13,233,727.24 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

**HORIZONTAL ORIGIN**

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D.HENRY

Point Source:

JONAS 1932
PARRISH

**MOST RECENT RECOVERY**

03/23/93 NEW

| VERTICAL | feet | meters |
|---|---|---|
| IGLD 1955: | 0.000 | 0.000 |
| IGLD 1985: | 0.000 | 0.000 |
| NAVD 1988: | 0.000 | 0.000 |
| NGVD 1929: | 0.000 | 0.000 |
| pt. source: | | |
| geoid. hgt: | 0.000 | 0.000 |

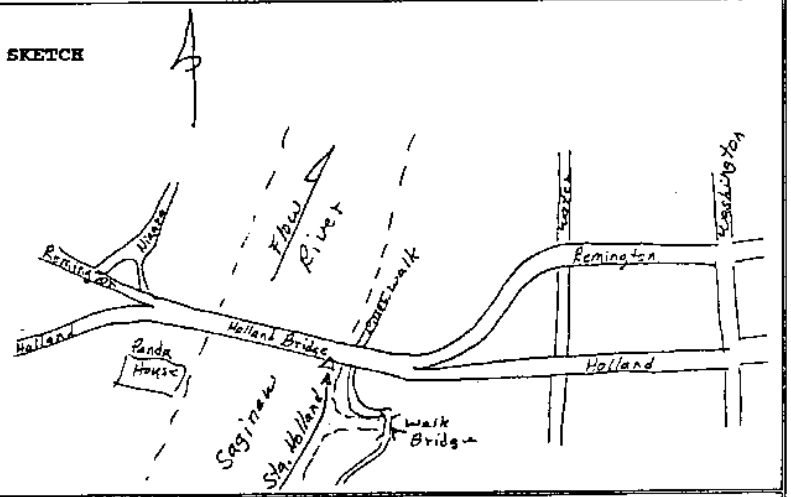
**PROPERTY OWNER**

firm:
P.O.C.
telephone:
access: , hike

**DESCRIPTION**

STATION HOLLAND IS A STANDARD BRASS DISK SET INTO A CONCRETE WALK ON THE UPSTREAM SIDE OF THE HOLLAND AVE. BRIDGE OVER THE SAGINAW RIVER. STATION IS ON THE EAST-BOUND SIDE OF SAID FOUR-LANE BRIDGE. REMINGTON ST. GOES TO THE WEST ACROSS THE BRIDGE AND HOLLAND ST. GOES TO THE EAST ACROSS THE BRIDGE.

**SKETCH**




Ref # SAG-0608

# SURVEY CONTROL DATA

Desig: HOLLAND

Office of Record: Saginaw Area Office

Printed on 11/04/93

**Figure D-27. (Sheet 5 of 6)**

U.S. ARMY ENGINEER DISTRICT - DETROIT

**GENERAL INFORMATION**

designation: GENESEE
reference no. SAG-0609

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.11N R.04E
section: 2

**HORIZONTAL**

datum: NAD83
lat: 43° 26' 1.64599" N
lon: 83° 56'34.06378" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 705,025.46 ft (US) N
X: 13,235,921.57 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

**HORIZONTAL ORIGIN**

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Source:

JONAS 1932
PARRISH

**MOST RECENT RECOVERY**
03/23/93 NEW

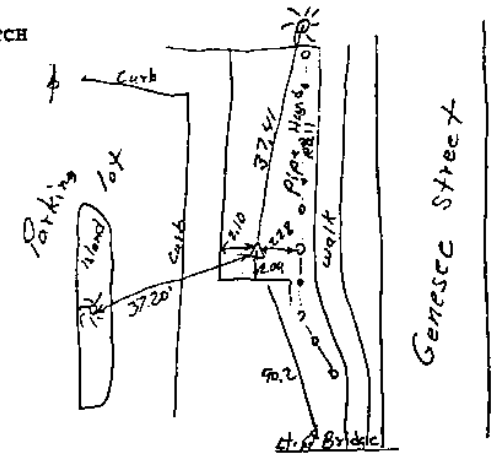
| VERTICAL | feet | meters |
|---|---|---|
| IGLD 1955: | 0.000 | 0.000 |
| IGLD 1985: | 0.000 | 0.000 |
| NAVD 1988: | 0.000 | 0.000 |
| NGVD 1929: | 0.000 | 0.000 |
| pt. source: | | |
| geoid. hgt: | 0.000 | 0.000 |

**PROPERTY OWNER**
firm:
P.O.C.
telephone:
access: car, boat

**DESCRIPTION**
STATION GENESEE IS A STANDARD BRASS DISK SET IN CONCRETE AT THE SOUTHEAST CORNER OF THE INTERSECTION OF WEST GENESEE & NORTH NIAGARA. STATION IS 100 FT. WEST OF THE GENESEE STREET BRIDGE OVER THE SAGINAW RIVER AND 50 FT. EAST OF NORTH NIAGARA. STATION IS ON CONCRETE THAT IS 2 FT. ABOVE THE PARKING LOT AND ON THE SOUTH SIDE OF THE HANDRAIL OF THE SIDEWALK. STATION IS 2.1 FT. NORTH OF CONCRETE EDGE, 2.09 FT. WEST OF CONCRETE EDGE, 2.28 FT. SOUTH OF HANDRAIL, AND 37.41 FT. EAST-SOUTHEAST OF LIGHTPOST AT STREET CORNER.

TO REACH STATION FROM THE INTERSECTION OF M-13 (WASHINGTON) AND I-675, GO SOUTH ON M-13 TO GENESEE AND TURN RIGHT, GO ACROSS THE RIVER TILL YOU COME TO NIAGARA ST.. STATION IS AT THIS INTERSECTION.

**SKETCH**




Ref # SAG-0609

# SURVEY CONTROL DATA

Desig: GENESEE

Office of Record: Saginaw Area Office

Printed on 11/04/93

Figure D-27. (Sheet 6 of 6)